(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 992 921 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
12.04.2000 Bulletin 2000/15

(51) Int Cl.7: G06F 17/30

(21) Application number: 99307465.7

(22) Date of filing: 21.09.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 29.09.1998 US 162494

(71) Applicant: LUCENT TECHNOLOGIES INC.
Murray Hill, New Jersey 07974-0636 (US)

(72) Inventor: Griffith, Gary L.
Arvada, Colorado 80005 (US)

(74) Representative:
Watts, Christopher Malcolm Kelway, Dr. et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green Essex, IG8 0TU (GB)

(54) Computer access dependent on the location of the accessing terminal

(57) Determining the location of a wireless terminal provides access to data stored in a database of a central computer associated with that location to the wireless terminal. The user of the wireless terminal is not required to perform any activity to gain access to data associated with the location. The degree of access to the data associated with a location is dependent upon the authorization information supplied by the wireless terminal to the central computer after the location of the wireless terminal has been determined. In addition, the wireless terminal may be a computer capable of wireless communication, a wireless PDA, or a wireless telephone set having display and data entry capabilities. In a first embodiment, a wireless terminal communicates with the central computer via a wireless switching system. The central computer determines the location of the wireless terminal upon establishment of a communication path between the wireless terminal and the central computer. In a second embodiment of the invention, the wireless terminal communicates via a wireless transceiver with the central computer. There is one wireless transceiver for each location. The transceivers are connected to the central computer by a local area network (LAN).

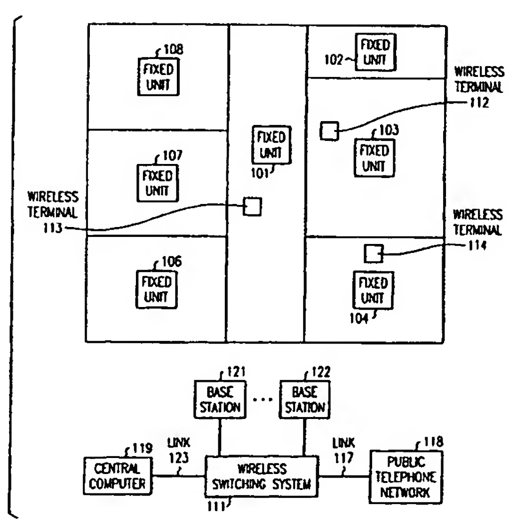


FIG. 1

EP 0 992 921 A2

Description

Technical Field

[0001] The present invention relates to wireless switching systems and, in particular, to providing remote computer access to an accessing terminal based on the location of that terminal.

Background of the Invention

[0002] In the modem commercial environment, there are many situations where it is desirable that computer access to information be based on the location of the terminal requesting that information. For example, when a doctor enters the room of a patient, the doctor wishes to access all records of the patient which are stored in a computer database. Even if the doctor is equipped with a laptop computer or PDA device, the doctor must enter the patient's identification in order to obtain this record. The need to enter the patient's identification is true even if the laptop computer or PDA device is communicating with the database computer via a wireless link. A nurse entering the patient's room also faces the same problem. Whereas, in normal situations, the time required to enter the patient's identification is simply a waste of a valuable resource and an inconvenience. It is possible to function in this manner. However, if an emergency occurs that is life threatening for the patient, there is not time for a doctor or a nurse to be operating a keyboard. Other situations arise in the commercial or military environments where the access to information is time critical.

Summary of the Invention

[0003] The aforementioned problems are solved and a technical advance is achieved in the art by an apparatus and method that determines the location of a wireless terminal and provid...
database c
cation to th
terminal is
access to c
geously, th
with a locati
formation su
computer af
been determ
be a compu
wireless PDA
and data ent
[0004] In a
municates w
switching syst
location of the
a communica
and the centr

① - fixed unit indicates location to wireless RWD which then indicates position to server; OR -
② (Next page) Transceivers receive messages from RWDs & contact the server. - In either case have only 1 data set per room.

the invention, the wireless terminal communicates via a wireless transceiver with the central computer. There is one wireless transceiver for each location. The transceivers are connected to the central computer advantageously by a local area network (LAN).

[0005] Other and further aspects of the present invention will become apparent during the course of the following description by reference to the accompanying drawing.

Brief Description of the Drawing

[0006]

FIG. 1 illustrates, in block diagram form, a system for implementing the first embodiment of the invention;
FIG. 2 illustrates, in block diagram form, a system for implementing the second embodiment of the invention;
FIGS. 3 and 4 illustrate tables and a database utilized by a central computer;
FIGS. 5 and 6 illustrate, in flow chart form, steps performed by a central computer in a first implementation of the invention;
FIG. 7 illustrates, in block diagram form, a fixed unit;
FIG. 8 illustrates, in block diagram form, a wireless telephone;
FIG. 9 illustrates, in flow chart form, steps performed by a wireless terminal;
FIG. 10 illustrates, in block diagram form, steps performed by a fixed unit;
FIG. 11 illustrates, in flow chart form, steps performed by a central computer in a second implementation of the invention;
FIG. 12 illustrates, in block diagram form, a transceiver;
FIG. 13 illustrates, in block diagram form, a laptop computer configured as a wireless terminal;
. 14 illustrates a table for utilization by a central
puter; and
15 illustrates a table and database for utiliza-
by a central computer.

Description

FIG. 1 illustrates, in block diagram form, a first
ent of the invention. Wireless terminals
re interconnected to central computer 119 via
ons 121-122 and wireless switching system
. 1, when a wireless terminal enters a new
receives the identification of the fixed unit
overage for that location. The wireless termi-
onsive to the identification information from
nit received via a transmission media other
sed by wireless switching system 111 to es-
ta communication path to central computer
ase station and wireless switching system

111. The wireless terminal then transmits to central computer 119 the identification information of the fixed unit. In response; central computer 119 determines the data that is assigned to that location. Central computer 119 then obtains the identification information of the wireless terminal. Central computer 119 determines what portion of the data assigned to the location can be accessed by the wireless terminal based on the identity of the wireless terminal. This portion of the data is referred to as authorized data. Central computer 119 is then responsive to requests from the wireless terminal to give the wireless terminal access to the authorized data. In addition, the wireless terminal can update portions of authorized data by the transmission of messages to central computer 119. If the system illustrated in FIG. 1 is serving a hospital, a doctor walking into a patient's room would have full access to the patient's records stored in central computer 119. However, a nurse would be given access only to a portion of the patient's records stored on central computer 119.

[0008] The wireless terminals may be laptop computers with a wireless interface designed to function with wireless switching system 111, PDAs similarly equipped, or wireless telephone sets. In addition, the transfer of data from central computer 119 to a wireless terminal may be in the form of text, video, or audio formats. For example, an individual delivering supplies or food to a patient in a hospital may only need to know the name of the patient. In such a situation, a wireless telephone would be very adequate for receiving audio information defining the name of the patient.

[0009] One skilled in the art could readily see that other methods could be utilized to determine the location of a wireless terminal. For example, the wireless terminals could transmit identification information defining the wireless terminal to a fixed unit which then could relay this to central computer 119 via wired or wireless media to central computer 119. In addition, global positioning satellite (GPS) devices or base stations could be used to determine a position of a wireless terminal.

[0010] FIG. 2 illustrates, in block diagram form, a second embodiment of the invention. Wireless transceivers 201-206 each provide coverage for an individual location. When wireless terminal 209 enters the area that is covered by transceiver 202, a wireless communication link is established between wireless terminal 209 and wireless transceiver 202. Upon establishment of this link, transceiver 202 communicates via LAN 207 the identity of wireless terminal 209 and the identification information of transceiver 202. Central computer 208 then requests the identification information from wireless terminal 209. Based on the identification information from wireless terminal 209 and the location as defined by the identification of transceiver 202, central computer 208 authorizes access to portions of the data assigned to the location covered by transceiver 202. Wireless terminal 209 then is free to read and write the authorized data.

[0011] Central computer 119 utilizes Table 301 of FIG. 3 to maintain at which location a wireless terminal is. When a wireless terminal changes location, central computer 119 determines this by detecting that the location in FIG. 3 is no longer the real location of the wireless terminal.

[0012] FIG. 4 illustrates database 401 in which data assigned to each location is maintained and Table 402. Table 402 comprises pointers which are constructed based on location pointers into database 401 and the terminals' authorization codes. The terminal authorization codes are determined by central computer 119 based on the location information and the identification information of the wireless terminal.

[0013] FIGS. 5 and 6 illustrate, in flow chart form, the steps performed by central computer 119 in implementing the first embodiment of the invention. Decision block 501 determines if there is a message from a wireless handset. If the answer is no, control is transferred to block 502 which performs normal processing before returning control back to decision block 501. If the answer in decision block 501 is yes, decision block 507 determines if a "no fixed unit" message is being received from a wireless telephone. Such a message indicates that a wireless telephone is not receiving the transmission signal from any fixed unit. If the answer is yes in decision block 507, control is transferred to block 504 which determines the last known location. Central computer 119 maintains a list of last known locations for each of the wireless terminals. Block 506 then signals that the wireless telephone cannot receive a fixed unit around the last location listed for the wireless telephone. This signaling may be in the form of a message displayed to an operator of central computer 119 or merely a message being included in a maintenance log of central computer 119. After execution of block 506, control is transferred back to decision block 501.

[0014] Returning to decision block 507, if the answer is no, decision block 508 determines if a low battery indication was included in the message identifying the fixed unit from the wireless telephone. If the answer is no in decision block 508, block 509 determines the location based on the identification code of the fixed unit of the wireless telephone before transferring control to decision block 601 of FIG. 6. If the answer in decision block 508 is yes, the low battery indication for the identified fixed unit is placed in the database, and a maintenance message indicating low battery is generated before transferring control to block 512. Block 512 performs the same operations as block 509 before transferring control to decision block 601 of FIG. 6.

[0015] Control is transferred to decision block 601 of FIG. 6 from either block 509 or block 512. Decision block 601 determines if the wireless terminal has changed its location. This is performed by utilizing the determined location in comparison with the location given for the terminal in Table 301 of FIG. 3. If the wireless terminal has changed locations, block 608 updates Table 301 (also

referred to as Table 1 in FIG. 6) to reflect this new location, and block 609 requests the identification information from the wireless terminal by a message transmitted via wireless switching system 111. Decision block 611 determines when the identification information is received from the wireless terminal. When the identification information is received, control is transferred to block 612 which determines the authorized access to the location's data that is to be given to the wireless terminal. Block 613 stores this authorized access information into Table 402 of FIG. 4 (also referred to as Table 2 in FIG. 6) before returning control back to decision block 501 of FIG. 5.

[0016] Returning to decision block 601, if the wireless terminal has not changed location, control is transferred to decision block 602 which determines if the wireless terminal is authorized to access information in database 401 of FIG. 4 assigned to the particular location. Decision block 602 makes this determination by determining if there is a entry for the wireless terminal in column 412 of Table 402 of FIG. 4. If the answer is no in decision block 602, control is transferred to error recovery in block 603. If the answer is yes, control is transferred to decision block 604 which determines if the wireless terminal is requesting access to database 401. If the answer is no, control is transferred to block 606. The latter block performs normal processing before returning control back to decision block 501 of FIG. 5. If the answer is yes in decision block 604, block 607 performs the requested access to database 401 utilizing the pointer that comprises an entry from column 409 and an entry from column 411 of Table 402 of FIG. 4 to access the appropriate portion of database 401. After execution of block 607, control is transferred back to decision block 501 of FIG. 5.

[0017] FIG. 7 illustrates in block diagram form a fixed unit. The fixed unit of FIG. 7 is powered by battery 701. However, one skilled in the art could readily see that normal building AC power could also be utilized to power the fixed unit. Controller 703 periodically transmits the identification code for the fixed unit via transmitter 704. Advantageously, transmitter 704 can be transmitting utilizing infrared transmission or ultrasonic transmission. Transmitters for transmitting either infrared or ultrasonic are well known in the art. If controller 703 detects that battery 701 is at a low power level via conductor 707, battery monitor 702, and conductor 708, controller 703 sets alarm indicator 705 and transmits the low power indication along with the identification code via transmitter 704.

[0018] Wireless handset 112 is illustrated in greater detail in FIG. 8. Wireless handset 112 implements a wireless protocol that allows wireless handset 112 to maintain a wireless signal link with wireless telecommunication system controller 111 via base stations 121-122. One air interface that can be used is the Japanese PHS protocol as set forth in "User-Network Interface and Inter-Network Interface Standards for PHS", the Telecommunication Technology Committee, 1995, and "Personal Handy Phone System RCR Standard", Version 1, RCR STD-28, December 20, 1993. The message set of the PHS protocol is similar to the ISDN message set. Overall control of the wireless handset is provided by control unit 801. Units 802, 803, 806, 807, 808, and 809 provide the RF communication capabilities for the wireless handset. Elements 804, 810, and 811-814 provide the audio information received and transmitted to the user; whereas, elements 816-818 and 805 provide the basic user interface. The PHS protocol allows control unit 801 to establish a logical data channel with system controller 111. Control unit 801 utilizes this logical data channel to transmit identification information for fixed units to system controller 111 which in turn transfers this information to central computer 119 of FIG. 1 using well known methods. Fixed unit receiver 321 receives the identification code of a fixed unit and transfers this identification code to control unit 801 for transmission to central computer 119. Fixed unit receiver 321 is of a design well known in the art for either infrared or ultrasonic transmission media. One skilled in the art could readily see that fixed unit receiver 321 could provide to control unit 801 the signal strength of the received signal. Further, control unit 801 could also tune fixed unit receiver 321 to receive different frequencies or other variations of the transmission media using well known techniques in the art.

[0019] FIG. 9 illustrates the steps performed by a wireless terminal such as wireless handset 113. Decision block 901 determines if the time has elapsed to monitor for a fixed unit. Advantageously, every second the wireless handset monitors to determine if the transmission signal of a fixed unit is being received. If the answer in decision block 901 is no, normal processing is performed by block 902 before control is returned back to decision block 901.

[0020] If the answer in decision block 901 is yes, control is transferred to decision block 903 which determines if a transmission signal is being detected. If the answer in decision block 903 is no, control is transferred to block 904 which establishes a logical channel to central computer 119 via a base station and system controller 111. After the establishment of the logical channel, the wireless handset transmits a "no fixed unit" message to the central computer before transferring control back to decision block 901. Returning to decision block 903, if the answer is yes, control is transferred to block 908 which establishes a logical channel to central computer 119. Block 909 determines the identification code of the fixed unit whose transmission signal is being received, and block 911 transmits the received identification code to central computer 119 before transferring control to decision block 912. Decision block 912 determines if a low battery indication was included in the transmission signal from the fixed unit. If the answer is no, control is transferred back to decision block 901. If the answer in decision block 912 is yes, block 913 transmits a low bat-

tery indication message to central computer 119 for the identified fixed unit.

[0021] FIG. 10 illustrates the steps performed by a fixed unit. Decision block 1001 determines if it is time to transmit the identification code of the fixed unit. Advantageously, the identification code is transmitted every tenth of a second. If the answer is no, control is transferred back to decision block 1001. If the answer is yes, decision block 1003 determines if battery monitor 702 of FIG. 7 is indicating a low battery. If the answer is no, block 1004 simply transmits the identification code of the fixed unit before transferring control back to decision block 1001. If the answer in decision block 1003 is yes, block 1006 transmits a message that includes the identification code and a low battery indication before transferring control back to decision block 1001.

[0022] FIG. 11 illustrates, in flow chart form, the steps performed by central computer 208 in implementing the second embodiment of the invention. Central computer 208 maintains an internal table which specifies the locations of transceivers 201-206. When a message is received from a wireless terminal via one of the transceivers, control is transferred to block 1105. The latter block determines the location of the wireless terminal based on the internal table that specifies the location of the transceiver being utilized by the wireless terminal. The identification of the transceiver is included in each message sent by the transceiver to central computer 208 via LAN 207. After execution of block 1105, control is transferred to block 1101.

[0023] Decision block 1101 determines if the wireless terminal has changed its location. This is performed by utilizing the determined location in comparison with the location given for the terminal in Table 1401 of FIG. 14 (also referred to as Table 1 in FIG. 11). If the wireless terminal has changed locations, block 1108 updates Table 1401 to reflect this new location, and block 1109 requests the identification information from the wireless terminal by a message transmitted via central computer 208. Decision block 1111 determines when the identification information is received from the wireless terminal. When the identification information is received, control is transferred to block 1112 which determines the authorized access to the location's data that is to be given to the wireless terminal. Block 1113 stores this authorized access information into Table 1502 of FIG. 15 (also referred to as Table 2 in FIG. 11) before returning control back to decision block 1100. Returning to decision block 1101, if the wireless terminal has not changed location, control is transferred to decision block 1102 which determines if the wireless terminal is authorized to access information in database 1501 of FIG. 15 assigned to the particular location. Decision block 1102 makes this determination by determining if there is a entry for the wireless terminal in column 1512 of Table 1502 of FIG. 15. If the answer is no in decision block 1102, control is transferred to error recovery in block 1103. If the answer is yes, control is transferred to decision block 1104 which determines if the wireless terminal is requesting access to database 1501. If the answer is no, control is transferred to block 1106. The latter block performs normal processing before returning control back to decision block 1100. If the answer is yes in decision block 1104, block 1107 performs the requested access to database 1501 utilizing the pointer that comprises an entry from column 1509 and an entry from column 1511 of Table 1502 of FIG. 15 to access the appropriate portion of database 1501. After execution of block 1107, control is transferred back to decision block 1100.

[0024] FIG. 12 illustrates, in block diagram form, transceiver 202 of FIG. 2. The other transceivers of FIG. 2 are identical in design. Controller 1201 transmits and receives messages with central computer 208 via LAN interface 1202 and LAN 207. The design of LAN interface 1202 is well known in the art and can be designed to utilize a number of different LAN protocols. Controller 1201 communicates with wireless terminals via infrared (IR) transmitter 1203 and IR receiver 1204. One skilled in the art could readily envision that the transmission medium could be other than infrared such as electromagnetic. Controller 1201 periodically transmits its identification information via IR transmitter 1203 at predefined times. When a wireless terminal receives these periodic transmissions, the wireless terminal transmits via IR receiver 1204 the identification of the wireless terminal. Controller 1201 then forms a message consisting of the identification of the wireless terminal and the identification of transceiver 202 and transmits this message via LAN interface 1202 and LAN 207 to central computer 208. Controller 1201 can be communicating with a number of wireless terminals at any given time. This allows a number of wireless terminals to be in the location covered by transceiver 202. Controller 1201 is responsive to messages received from central computer 208 via LAN interface 1202 and LAN 207 to form a message utilizing the wireless terminal identification that was included in the message from central computer 208. This formed message is then transmitted via IR transmitter 1203. The wireless terminals constantly monitor transmissions from controller 1201 and will only respond to those messages which contain the wireless terminal's identification information. This allows central computer 208 to communicate with individual wireless terminals.

[0025] FIG. 13 illustrates, in block diagram form, wireless terminal 112. The other wireless terminals illustrated in FIG. 2 would be similar in design. However, laptop computer 1301 may be replaced with a PDA. Laptop computer 1301 is responsive to the periodic polling message received from a transceiver to transmit back a message defining the identity of wireless terminal 112. Laptop computer 1301 is responsive to messages received from central computer 208 to take the appropriate actions. For example, laptop computer 130t is responsive to a message from central computer 208 requesting the identification information of laptop computer 1301 to transmit that information to central computer

208. Laptop computer 1301 also is running an application program that requests and utilizes data stored in database 1501 of FIG. 15.

Claims

1. A method for accessing data, comprising the steps of:

   assigning (FIG. 4) one of a plurality of data sets (403,404) to each of a plurality of locations;
   determining (601, 608) one of the plurality of locations in which a data device (113) is located;
   identifying (602) one of the plurality of data sets assigned to the determined one of the plurality of locations; and
   providing (607) access to the data device to the one of the plurality of data sets.

2. The method of claim 1 wherein each of the plurality of data sets comprises subsets of data and the method further comprises the steps of requesting (611) an identification of the data device; and
   limiting the access of the data device to predefined ones of the subset of data of the one of the plurality of data sets based on the identification of the data device.

3. The method of claim 1 or claim 2 wherein the data device is interconnected to a wireless switching system (111) and the step of determining comprises the step of supplying (909, 911) location information by the data device to a database computer (119) via the wireless switching system whereby the location information identifies the one of the plurality of locations.

4. The method of claim 3 wherein the step of supplying comprises the step of receiving (909) the location information from one of a plurality of fixed units by the data device whereby each of the plurality of fixed units is located in one of the plurality of locations.

5. The method of claim 1 or claim 2 wherein the data device is interconnected to a local area network (107) via a wireless connection through one of a plurality of fixed units (202) that is connected to the local area network and the step of determining comprises the step of supplying (1101) location information by the one of the plurality of fixed units to a database computer (119) via the local area network whereby the location information identifies the one of the plurality of locations.

6. The method of claim 5 wherein each of the plurality of fixed units is located in one of the plurality of locations and is connected to the local area network.

7. The method of claim 5 or 6 wherein the step of identifying the one of the plurality of data sets assigned to the determined one of the plurality of locations is performed in response to the received location information by the database computer.

8. The method of claim 7 wherein the step of providing access to the data device to the one of the plurality of data sets is performed by the database computer via the one of the plurality of fixed units and the local area network.

9. The method of any of the preceding claims wherein the data device is a computer.

10. The method of any of claims 1 to 8 wherein the data device is a PDA.

11. The method of any of claims 1 to 8 wherein the data device is a wireless telephone.

12. An apparatus for accessing data, comprising means arranged to carry out each step of a method as claimed in any of the preceding claims.

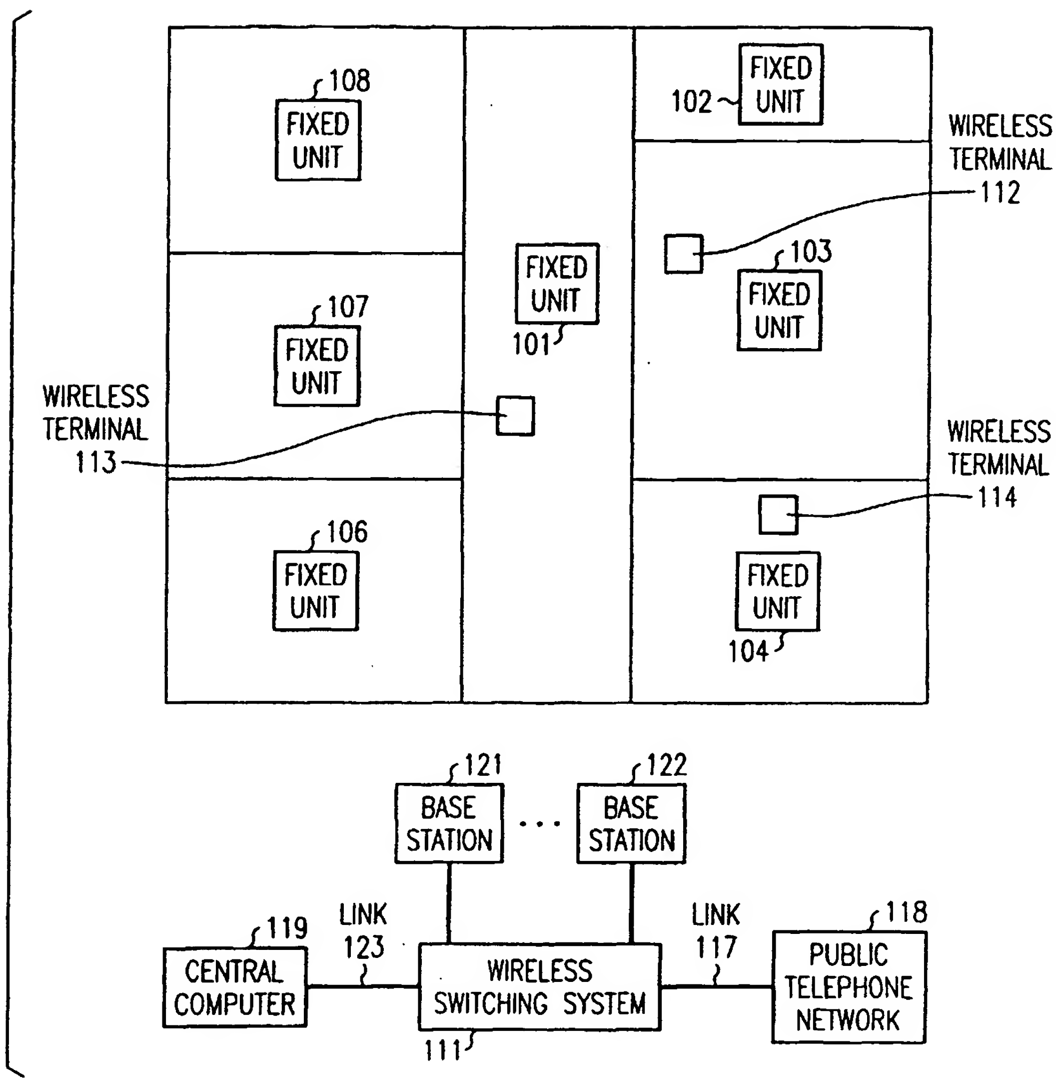

FIXED UNIT
108
FIXED UNIT
107
FIXED UNIT
106
FIXED UNIT
101
FIXED UNIT
102
FIXED UNIT
103
FIXED UNIT
104
WIRELESS TERMINAL 112
WIRELESS TERMINAL 113
WIRELESS TERMINAL 114
BASE STATION
121
BASE STATION
122
CENTRAL COMPUTER
119
LINK 123
WIRELESS SWITCHING SYSTEM
111
LINK 117
PUBLIC TELEPHONE NETWORK
118

FIG. 1

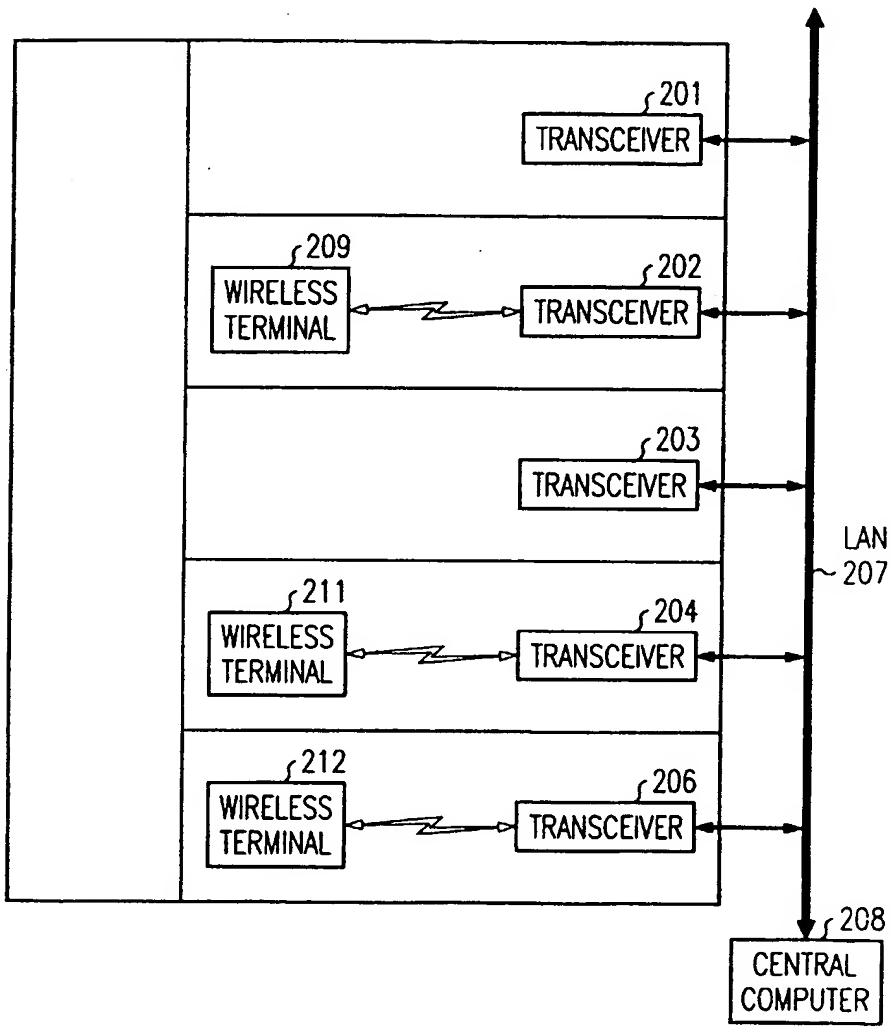

201
TRANSCEIVER
209
WIRELESS TERMINAL
202
TRANSCEIVER
203
TRANSCEIVER
LAN 207
211
WIRELESS TERMINAL
204
TRANSCEIVER
212
WIRELESS TERMINAL
206
TRANSCEIVER
208
CENTRAL COMPUTER

FIG. 2

TABLE 301

WIRELESS TERMINAL	LOCATION
112	103
113	101
114	104

FIG. 3

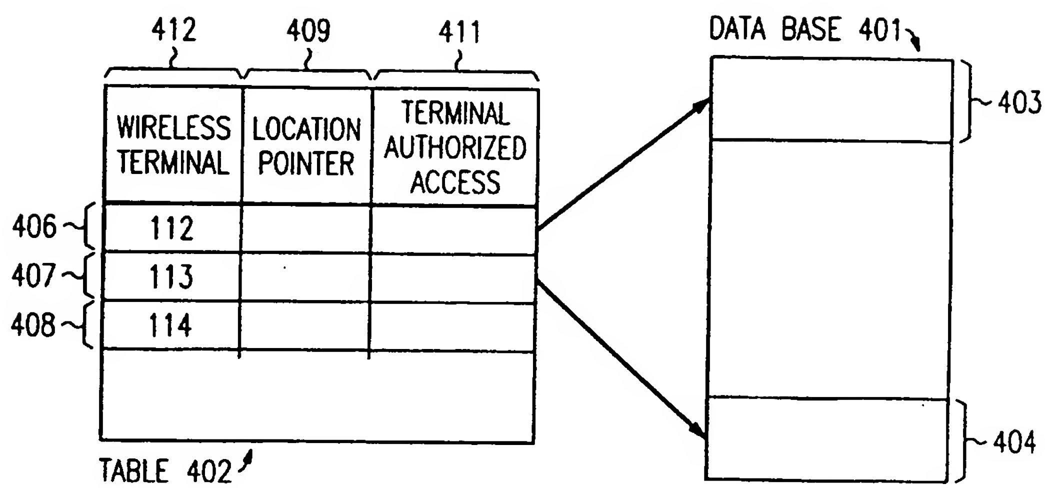
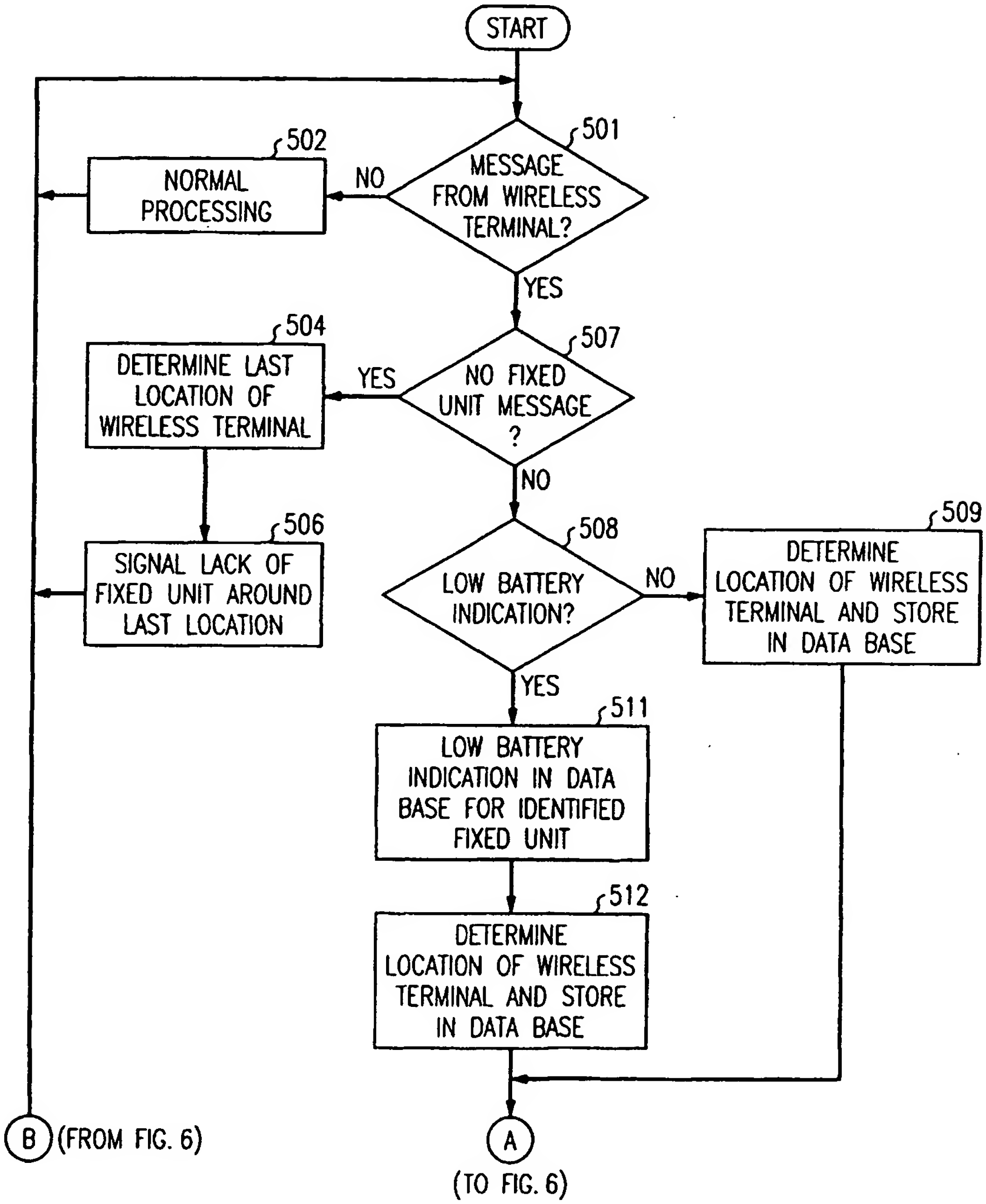


FIG. 4

FIG. 5


START
501
MESSAGE FROM WIRELESS TERMINAL?
NO
502
NORMAL PROCESSING
YES
507
NO FIXED UNIT MESSAGE ?
YES
504
DETERMINE LAST LOCATION OF WIRELESS TERMINAL
506
SIGNAL LACK OF FIXED UNIT AROUND LAST LOCATION
NO
508
LOW BATTERY INDICATION?
NO
509
DETERMINE LOCATION OF WIRELESS TERMINAL AND STORE IN DATA BASE
YES
511
LOW BATTERY INDICATION IN DATA BASE FOR IDENTIFIED FIXED UNIT
512
DETERMINE LOCATION OF WIRELESS TERMINAL AND STORE IN DATA BASE
B (FROM FIG. 6)
A
(TO FIG. 6)

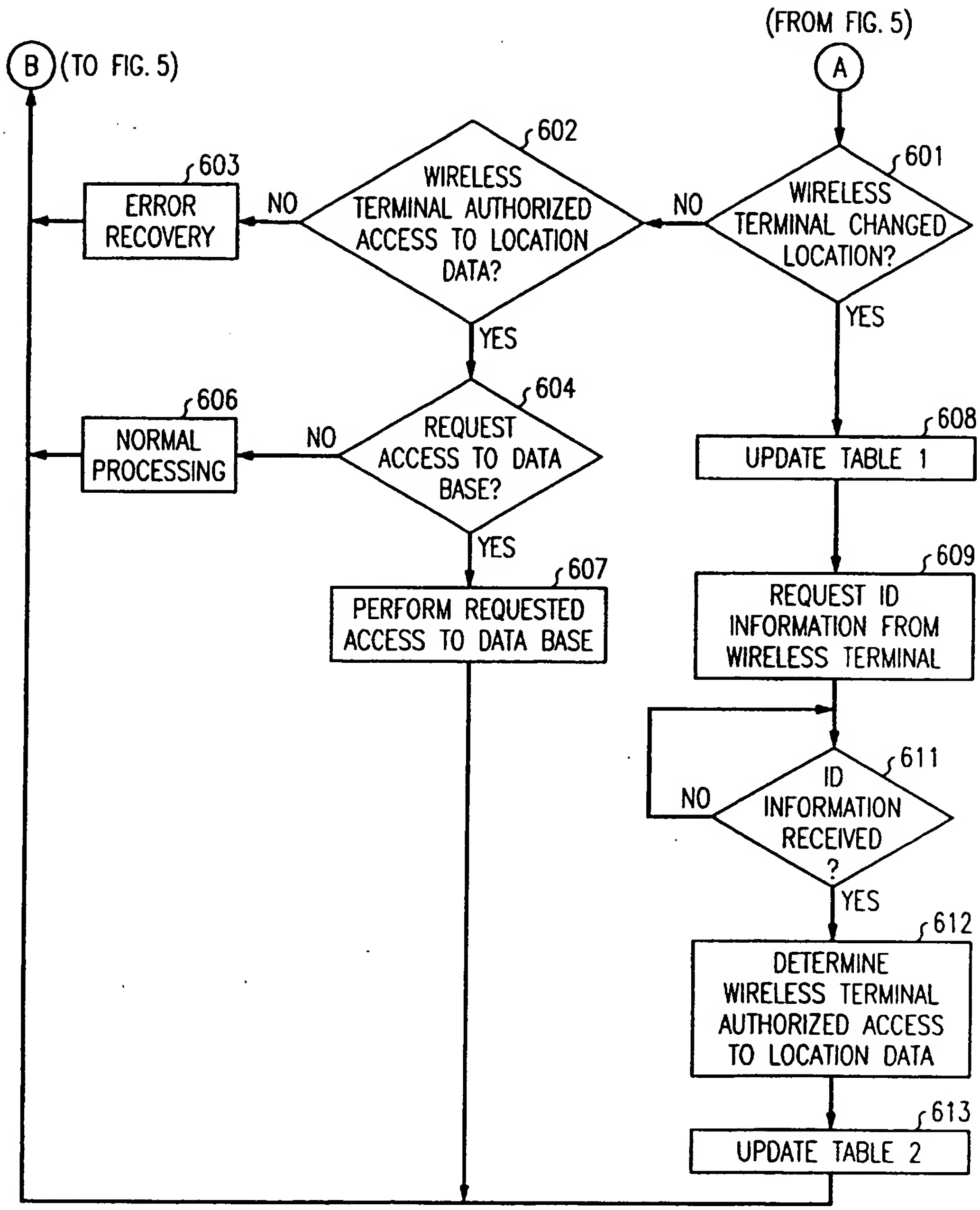

(FROM FIG. 5)
A
B
(TO FIG. 5)
601
WIRELESS TERMINAL CHANGED LOCATION?
NO
YES
602
WIRELESS TERMINAL AUTHORIZED ACCESS TO LOCATION DATA?
NO
YES
603
ERROR RECOVERY
604
REQUEST ACCESS TO DATA BASE?
NO
YES
606
NORMAL PROCESSING
607
PERFORM REQUESTED ACCESS TO DATA BASE
608
UPDATE TABLE 1
609
REQUEST ID INFORMATION FROM WIRELESS TERMINAL
611
ID INFORMATION RECEIVED ?
NO
YES
612
DETERMINE WIRELESS TERMINAL AUTHORIZED ACCESS TO LOCATION DATA
613
UPDATE TABLE 2

FIG. 6

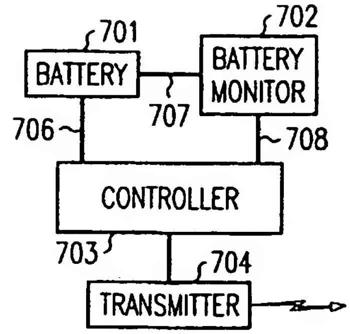

BATTERY
701
BATTERY MONITOR
702
707
706
708
CONTROLLER
703
704
TRANSMITTER

FIG. 7

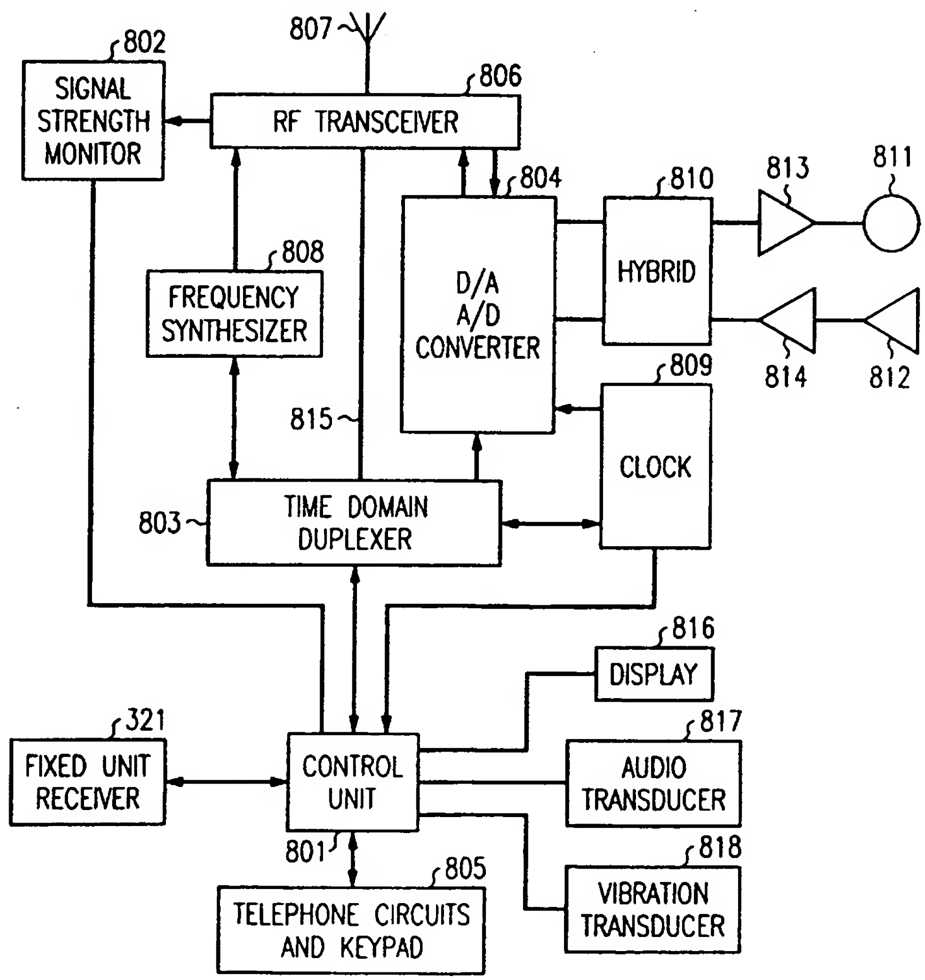

807
802
SIGNAL STRENGTH MONITOR
806
RF TRANSCEIVER
804
810
813
811
808
FREQUENCY SYNTHESIZER
D/A A/D CONVERTER
HYBRID
814
812
809
815
CLOCK
803
TIME DOMAIN DUPLEXER
816
DISPLAY
321
FIXED UNIT RECEIVER
CONTROL UNIT
817
AUDIO TRANSDUCER
801
805
818
TELEPHONE CIRCUITS AND KEYPAD
VIBRATION TRANSDUCER

FIG. 8

FIG. 9

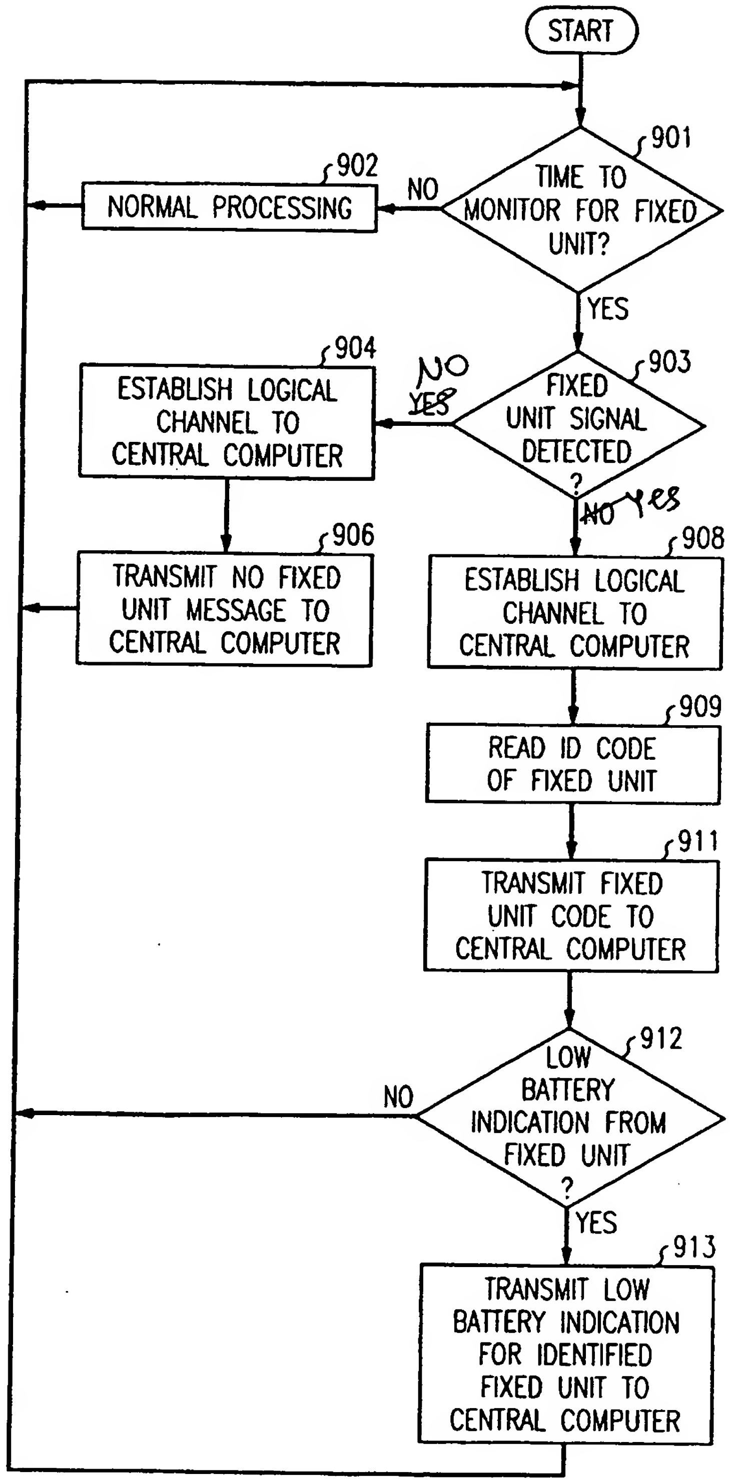

START
901
TIME TO MONITOR FOR FIXED UNIT?
NO
902
NORMAL PROCESSING
YES
903
FIXED UNIT SIGNAL DETECTED ?
NO
~~YES~~
904
ESTABLISH LOGICAL CHANNEL TO CENTRAL COMPUTER
906
TRANSMIT NO FIXED UNIT MESSAGE TO CENTRAL COMPUTER
~~NO~~ Yes
908
ESTABLISH LOGICAL CHANNEL TO CENTRAL COMPUTER
909
READ ID CODE OF FIXED UNIT
911
TRANSMIT FIXED UNIT CODE TO CENTRAL COMPUTER
912
LOW BATTERY INDICATION FROM FIXED UNIT ?
NO
YES
913
TRANSMIT LOW BATTERY INDICATION FOR IDENTIFIED FIXED UNIT TO CENTRAL COMPUTER

FIG. 10

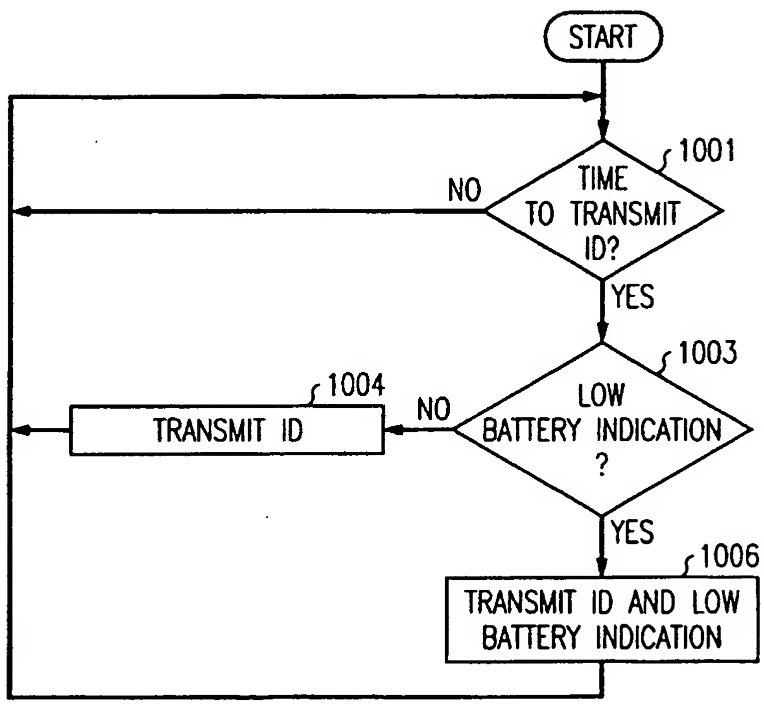
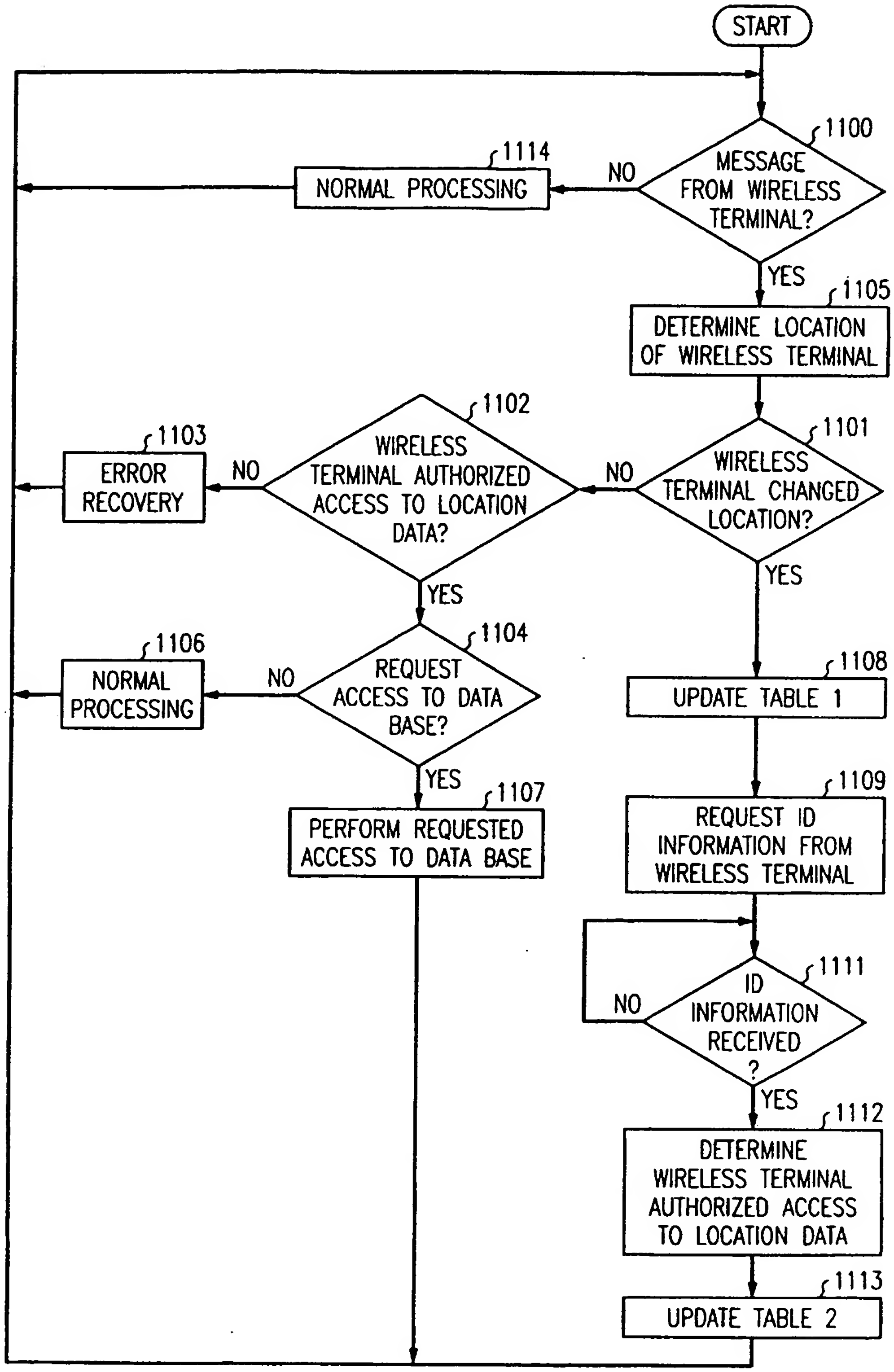

START
1001
NO
TIME TO TRANSMIT ID?
YES
1003
1004
TRANSMIT ID
NO
LOW BATTERY INDICATION ?
YES
1006
TRANSMIT ID AND LOW BATTERY INDICATION

FIG. 11


START
MESSAGE FROM WIRELESS TERMINAL?
1100
NO
YES
NORMAL PROCESSING
1114
DETERMINE LOCATION OF WIRELESS TERMINAL
1105
WIRELESS TERMINAL CHANGED LOCATION?
1101
NO
YES
WIRELESS TERMINAL AUTHORIZED ACCESS TO LOCATION DATA?
1102
NO
YES
ERROR RECOVERY
1103
REQUEST ACCESS TO DATA BASE?
1104
NO
YES
NORMAL PROCESSING
1106
PERFORM REQUESTED ACCESS TO DATA BASE
1107
UPDATE TABLE 1
1108
REQUEST ID INFORMATION FROM WIRELESS TERMINAL
1109
ID INFORMATION RECEIVED ?
1111
NO
YES
DETERMINE WIRELESS TERMINAL AUTHORIZED ACCESS TO LOCATION DATA
1112
UPDATE TABLE 2
1113

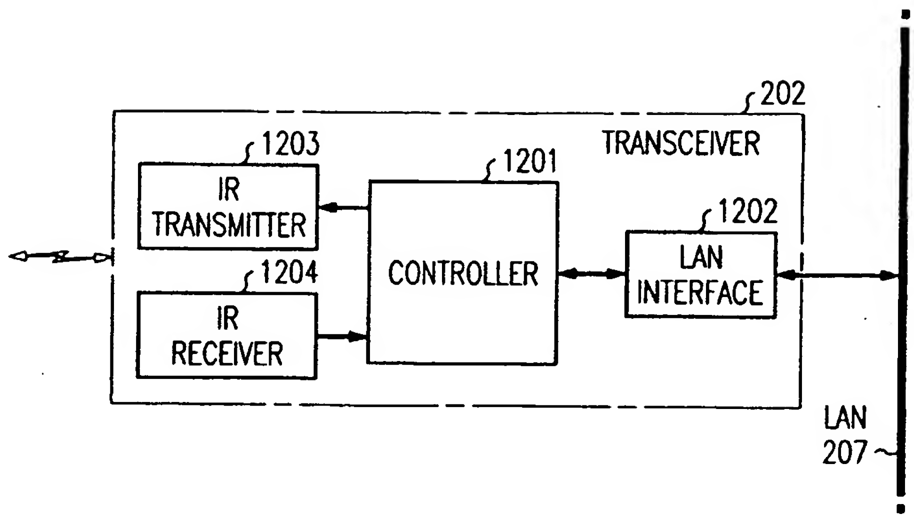

202
TRANSCEIVER
1203
IR TRANSMITTER
1201
CONTROLLER
1202
LAN INTERFACE
1204
IR RECEIVER
LAN 207

FIG. 12

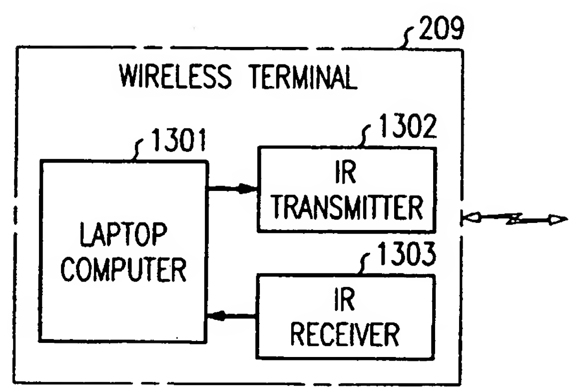

209
WIRELESS TERMINAL
1301
LAPTOP COMPUTER
1302
IR TRANSMITTER
1303
IR RECEIVER

FIG. 13

TABLE 1401

WIRELESS TERMINAL	LOCATION
209	202
211	204
212	206

FIG. 14

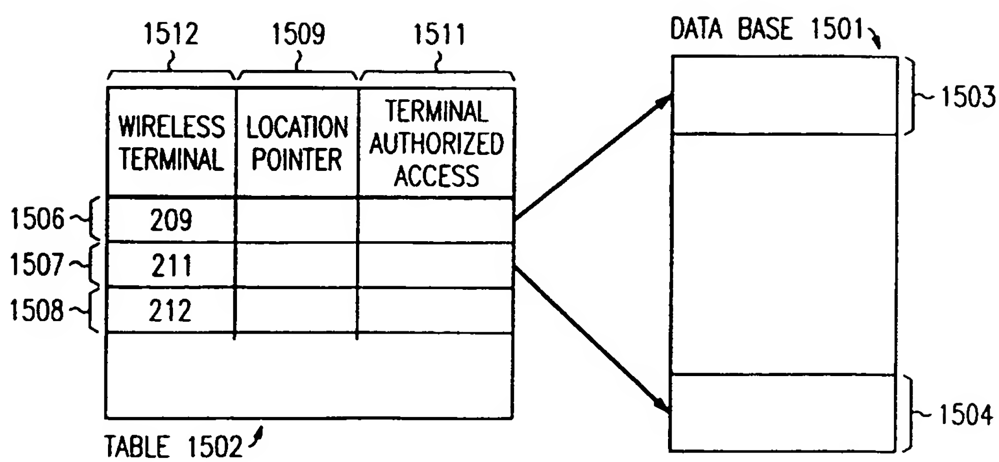


FIG. 15

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 992 921 A3

(12) **EUROPEAN PATENT APPLICATION**

(88) Date of publication A3:
17.01.2001 Bulletin 2001/03

(43) Date of publication A2:
12.04.2000 Bulletin 2000/15

(21) Application number: **99307465.7**

(22) Date of filing: **21.09.1999**

(51) Int Cl.[7]: **G06F 17/30**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **29.09.1998 US 162494**

(71) Applicant: **LUCENT TECHNOLOGIES INC.**
Murray Hill, New Jersey 07974-0636 (US)

(72) Inventor: **Griffith, Gary L.**
Arvada, Colorado 80005 (US)

(74) Representative: **Williams, David John et al**
Page White & Farrer,
54 Doughty Street
London WC1N 2LS (GB)

(54) **Computer access dependent on the location of the accessing terminal**

(57) Determining the location of a wireless terminal provides access to data stored in a database of a central computer associated with that location to the wireless terminal. The user of the wireless terminal is not required to perform any activity to gain access to data associated with the location. The degree of access to the data associated with a location is dependent upon the authorization information supplied by the wireless terminal to the central computer after the location of the wireless terminal has been determined. In addition, the wireless terminal may be a computer capable of wireless communication, a wireless PDA, or a wireless telephone set having display and data entry capabilities. In a first embodiment, a wireless terminal communicates with the central computer via a wireless switching system. The central computer determines the location of the wireless terminal upon establishment of a communication path between the wireless terminal and the central computer. In a second embodiment of the invention, the wireless terminal communicates via a wireless transceiver with the central computer. There is one wireless transceiver for each location. The transceivers are connected to the central computer by a local area network (LAN).

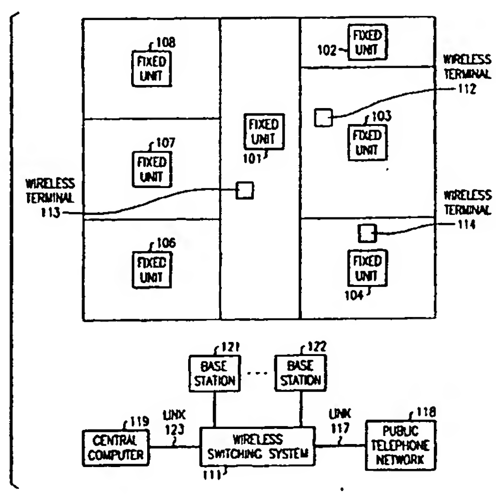


FIG. 1

EP 0 992 921 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 30 7465

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 603 054 A (GOLDSTEIN RICHARD J ET AL) 11 February 1997 (1997-02-11) * figures 1,2,9,14 * * column 2, line 20 - column 6, line 52 * * column 10, line 14 - column 10, line 29 * * column 14, line 25 - column 14, line 37 * * column 17, line 61 - column 20, line 12 * * column 22, line 41 - column 23, line 64 * ---	1-12	G06F17/30
X	FUJINO N ET AL: "MOBILE INFORMATION SERVICE BASED ON MULTI-AGENT ARCHITECTURE" IEICE TRANSACTIONS ON COMMUNICATIONS,JP,INSTITUTE OF ELECTRONICS INFORMATION AND COMM. ENG. TOKYO, vol. E80-B, no. 10, 1 October 1997 (1997-10-01), pages 1401-1406, XP000734533 ISSN: 0916-8516 * page 1401, column 2, line 15 - page 1401, column 2, line 21 * * page 1403, column 2, line 44 - page 1404, column 2, line 11 * * figures * ---	1,5-10, 12	
X	WO 98 02824 A (MOTOROLA INC) 22 January 1998 (1998-01-22)	1,5	
A	* page 2, line 24 - page 3, line 2 * * page 3, line 28 - page 4, line 6 * * page 8, line 16 - page 11, line 8 * --- -/--	2-12	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
G06F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 November 2000	Abbing, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 30 7465

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 598 572 A (TANIKOSHI KOICHIRO ET AL) 28 January 1997 (1997-01-28) * abstract * * column 8, line 5 - column 10, line 49 *	1,5	
A	US 4 835 372 A (GRIFFEE RICHARD A ET AL) 30 May 1989 (1989-05-30) * column 2, line 1 - column 6, line 18 *	1-8	
A	EP 0 853 287 A (NOKIA MOBILE PHONES LTD) 15 July 1998 (1998-07-15) * abstract * * figures 1,2 * * claims *	1,5,9-11	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 November 2000	Abbing, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 30 7465

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

21-11-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5603054 A	11-02-1997	US 5555376 A	10-09-1996
		US 5717955 A	10-02-1998
		US 5611050 A	11-03-1997
		US 5544321 A	06-08-1996
WO 9802824 A	22-01-1998	US 5974447 A	26-10-1999
		AU 3408797 A	09-02-1998
		BR 9710723 A	17-08-1999
		CA 2260264 A	22-01-1998
		CN 1230265 A	29-09-1999
		EP 0912946 A	06-05-1999
US 5598572 A	28-01-1997	JP 7262225 A	13-10-1995
		DE 19509836 A	21-09-1995
US 4835372 A	30-05-1989	US 5640301 A	17-06-1997
		US 5179569 A	12-01-1993
		US 5307372 A	26-04-1994
		CA 1261968 A	26-09-1989
		EP 0230458 A	05-08-1987
		JP 63500546 T	25-02-1988
		WO 8700659 A	29-01-1987
EP 0853287 A	15-07-1998	FI 965278 A	01-07-1998
		CA 2225191 A	30-06-1998
		JP 10257100 A	25-09-1998

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01S 11/06

A2

(11) International Publication Number: WO 00/50919

(43) International Publication Date: 31 August 2000 (31.08.00)

(21) International Application Number: PCT/US00/04902

(22) International Filing Date: 25 February 2000 (25.02.00)

(30) Priority Data:
60/121,612 25 February 1999 (25.02.99) US

(71) Applicant: MICROSOFT CORPORATION [US/US]; One Microsoft Way, Redmond, WA 98052 (US).

(72) Inventors: BAHL, Paramvir; 2221 271st Ct SE, Issaquah, WA 98029 (US). PADMANABHAN, Venkata, N.; 14616 NE 36th Street, #E-16, Bellevue, WA 98007 (US).

(74) Agents: VASILJEVIC, Vladan, M. et al.; Leydig, Voit & Mayer, Ltd., Suite 4900, Two Prudential Plaza, 180 North Stetson, Chicago, IL 60601-6780 (US).

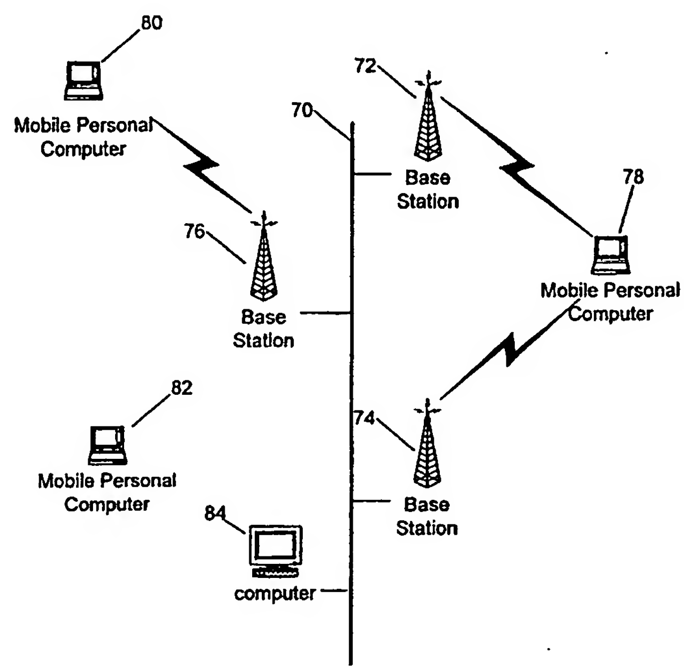
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: USING A DERIVED TABLE OF SIGNAL STRENGTH DATA TO LOCATE AND TRACK A USER IN A WIRELESS NETWORK

(57) Abstract

A method for locating a user in a wireless network is disclosed. A mobile computer seeking to determine its location within a building detects the signal strength of one or more wireless base stations placed at known locations throughout the building. The mobile computer uses this measured signal strength to determine its location via a signal-strength-to-location table look-up. A table of known locations within the building and the base station signal strength at those locations is searched to find the most similar stored signal strengh to the signal strength detected. The location corresponding to the most similar stored signal strength is determined to be the current location of the mobile computer. Alternatively, a number of signal strengths from the table can be used and the corresponding locations can be spatially averaged to determine the location of the mobile computer. The table can be derived empirically, by placing a mobile computer at the known locations and detecting the signal strength of the wireless base stations at those locations, or the table can be derived mathematically by taking into account a reference signal strength, the distance between the reference point and the known location, and the number of walls between the reference point and the known location. As an alternative, the base stations can detect the signal strength of the mobile computer. In such a case, the table would relate a known position of the mobile computer to the signal strength of the mobile computer at that location as detected by the one or more base stations.



USING A DERIVED TABLE OF SIGNAL STRENGTH DATA TO LOCATE AND TRACK A USER IN A WIRELESS NETWORK

TECHNICAL FIELD

This invention relates generally to determining the location of an object and tracking the object and, more particularly, relates to locating and tracking a user of a wireless network.

BACKGROUND OF THE INVENTION

Advances in the Global Positioning System (GPS) have provided non-military users an inexpensive and portable location and tracking device. Currently the GPS system is used to provide directions to drivers through an in-vehicle system, provide location and tracking information for marine navigation, and allow shipping companies to locate and track individual shipments. However, the GPS system is severely limited in an indoor environment.

The GPS system relies on the timing of signals from GPS satellites received by individual GPS units on the ground. Thus, an unobstructed view to the satellites is necessary to receive the signal. In an indoor environment, such an unobstructed view is, in general, not possible to obtain. Furthermore, the principal objective in developing GPS was to offer the United States military accurate estimates of position, velocity and time. Civil users of GPS were to be provided only "reasonable" accuracy consistent with national security concerns. As a result, satellite signals are purposefully degraded under a government policy called Selective Availability and consequently the resolution provided by the system is no more than 100 meter for civilian users. This coarse resolution is

inadequate for many applications and compounds the problem of the ineffectiveness of GPS indoors.

Because of these limitations, other technologies have been developed to locate and track users or objects in an in-building environment. One such system uses tags placed on the items that are to be tracked. The tags can be either active or passive. An active tag contains power circuitry, which can communicate with base stations. A passive tag contains no internal power, rather it is charged either inductively or electromagnetically as it passes within the range of a base station. Using this derived power, the passive tag communicates with the station. The base stations are physically linked together through a wired or wireless network. Each tag transmits a code uniquely identifying itself. Thus, the location of the tag is determined to be in the vicinity of the base station with which the tag last communicated.

Such tag-based tracking and location systems, while being useful in an in-building environment, require a significant installation of specialized base stations. A tag-based system can only determine the location of the tags as being "near" a particular base station, consequently, to achieve a sufficiently high resolution a large number of base stations must be installed. Obtrusive tags have to be placed on every item that is to be tracked or located, and in the case of infra-red tags, the system operates only when there is a "line-of-sight" between the tag and a base station. For all these reasons location-determination technology based on tags has had very limited success.

SUMMARY OF THE INVENTION

Therefore, the present invention is generally directed to a system for locating and tracking a user in a building without a specialized infrastructure and with the ability to track without a line-of-sight between the user and a base station.

The present invention is also generally directed to a system for locating and tracking a user in a building using the existing Radio-Frequency (RF) Wireless Local Area Network (WLAN) infrastructure.

A Wireless Local Area Network (WLAN) consists of base stations connected to a wired network, and mobile devices which are "connected" to the WLAN through wireless communication with the base stations. The present invention uses the signal sensing ability of both the base station and the mobile device to determine the location of the mobile device, and thus the location of the user of the mobile device. The strength of the received signal from several base stations is measured by the mobile device. The mobile device then compares the signal strength from each of the base stations to a pre-computed table containing the base stations' signal strength at various known locations of the mobile device. From this comparison, the mobile device determines its location. Alternatively, the signal strength from the mobile device can be measured at a number of base stations. This signal strength is then compared by a central computer to a pre-computed table containing the mobile computer's signal strength at the base stations for various known locations of the mobile computer. From this table, the central computer determines the location of the mobile computer.

Additional features and advantages of the invention will be made apparent from the following detailed description of illustrative embodiments which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

While the appended claims set forth the features of the present invention with particularity, the invention, together with its objects and advantages, may be best understood from the following detailed description taken in conjunction with the accompanying drawings of which:

Figure 1 is a block diagram generally illustrating an exemplary computer system on which the present invention resides;

Figure 2 is a diagram generally illustrating a wireless network according to the present invention;

Figure 3 is a diagram generally illustrating a wireless network on one floor of an office building;

Figure 4 is a diagram generally illustrating the locations of empirical determinations of signal strength according to the present invention;

Figure 5 is a diagram generally illustrating the operation of a line-clipping algorithm; and

Figure 6 is a flow chart generally illustrating the operation of a mathematical derivation of a signal strength table according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Turning to the drawings, wherein like reference numerals refer to like elements, the invention is illustrated as being implemented in a suitable computing environment. Although not required, the invention will be described in the general context of computer-executable instructions, such as program modules, being executed by a personal computer. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the invention may be practiced with other computer system configurations, including hand-held devices, multi-processor systems, microprocessor based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, and the like. The invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

With reference to Figure 1, an exemplary system for implementing the invention includes a general purpose computing device in the form of a conventional mobile personal computer 20, including a processing unit 21, a system memory 22, and a system bus 23 that couples various system components including the system memory to the processing unit 21. The system bus 23 may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. The system memory includes read only memory (ROM) 24 and random access memory (RAM) 25. A basic input/output system (BIOS) 26, containing the basic routines that help to transfer information between elements within

the mobile personal computer 20, such as during start-up, is stored in ROM 24. The mobile personal computer 20 further includes a hard disk drive 27 for reading from and writing to a hard disk 60, a magnetic disk drive 28 for reading from or writing to a removable magnetic disk 29, and an optical disk drive 30 for reading from or writing to a removable optical disk 31 such as a CD ROM or other optical media.

The hard disk drive 27, magnetic disk drive 28, and optical disk drive 30 are connected to the system bus 23 by a hard disk drive interface 32, a magnetic disk drive interface 33, and an optical disk drive interface 34, respectively. The drives and their associated computer-readable media provide nonvolatile storage of computer readable instructions, data structures, program modules and other data for the mobile personal computer 20. Although the exemplary environment described herein employs a hard disk 60, a removable magnetic disk 29, and a removable optical disk 31, it will be appreciated by those skilled in the art that other types of computer readable media which can store data that is accessible by a computer, such as magnetic cassettes, flash memory cards, digital video disks, Bernoulli cartridges, random access memories, read only memories, and the like may also be used in the exemplary operating environment.

A number of program modules may be stored on the hard disk 60, magnetic disk 29, optical disk 31, ROM 24 or RAM 25, including an operating system 35, one or more application programs 36, other program modules 37, and program data 38. A user may enter commands and information into the mobile personal computer 20 through input devices such as a keyboard 40 and a pointing device 42. Other input devices (not shown) may include a microphone, joystick, game pad, satellite dish, scanner, or the like. These and other input devices are often connected to the processing unit 21 through a serial port

interface 46 that is coupled to the system bus, but may be connected by other interfaces, such as a parallel port, game port or a universal serial bus (USB). A monitor 47 or other type of display device is also connected to the system bus 23 via an interface, such as a video adapter 48. In addition to the monitor, personal computers typically include other peripheral output devices, not shown, such as speakers and printers.

The mobile personal computer 20 may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer 49. The remote computer 49 may be another personal computer, a server, a router, a network PC, a peer device or other common network node, and typically includes many or all of the elements described above relative to the mobile personal computer 20, although only a memory storage device 50 has been illustrated in Figure 1. The logical connections depicted in Figure 1 include a Wireless Local Area Network (WLAN) 51 and a wide area network (WAN) 52. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets and the Internet.

When used in a WLAN networking environment, the mobile personal computer 20 is connected to the local network 51 through a wireless network interface or adapter 53. The wireless interface 53 transmits wireless packets to a base station 61. The base station 61 can then retransmit the packets, either through a wired or wireless network to the remote computer 49. When used in a WAN networking environment, the personal computer 20 typically includes a modem 54 or other means for establishing communications over the WAN 52. The modem 54, which may be internal or external, is connected to the system bus 23 via the serial port interface 46. In a networked environment, program modules depicted relative to the mobile personal computer 20, or

portions thereof, may be stored in the remote memory storage device. It will be appreciated that the network connections shown are exemplary and other means of establishing a communications link between the computers may be used.

In the description that follows, the invention will be described with reference to acts and symbolic representations of operations that are performed by one or more computers, unless indicated otherwise. As such, it will be understood that such acts and operations, which are at times referred to as being computer-executed, include the manipulation by the processing unit of the computer of electrical signals representing data in a structured form. This manipulation transforms the data or maintains it at locations in the memory system of the computer, which reconfigures or otherwise alters the operation of the computer in a manner well understood by those skilled in the art. The data structures where data is maintained are physical locations of the memory that have particular properties defined by the format of the data. However, while the invention is being described in the foregoing context, it is not meant to be limiting as those of skill in the art will appreciate that various of the acts and operation described hereinafter may also be implemented in hardware.

In accordance with the invention, an exemplary WLAN is shown in Figure 2. The base stations 72, 74, and 76 are the same as base station 61 in Figure 1, however, for clarity, each base station has been separately numbered so that each can be referred to individually. Similarly, mobile personal computers 78, 80, and 82 are all of the same type as mobile personal computer 20 described above. With reference to Figure 2, the mobile computer 78 can communicate, via wireless communication, with either base station 72 or base station 74 as shown. In a known manner, the mobile computer 78 can

select the base station which provides the highest signal strength, measured by the signal-to-noise ratio (SNR). The base stations 72, 74, and 76 can be connected by connection 70, which can be either a wired or wireless network. Therefore, to link two computers together, the WLAN passes messages through the base stations. For example, to communicate with mobile computer 80, mobile computer 78 can contact either base station 72 or base station 74. These base stations will then relay the message, through connection 70, to base station 76, which is the base station with which mobile computer 80 may currently be communicating. Base station 76 will then transmit the message to mobile computer 80, completing the wireless connection between mobile computers 78 and 80.

Because the mobile computers 78, 80, and 82 can be transported, the WLAN defines a mechanism by which communication between the mobile computers and the WLAN is transferred from one base station to another. The mobile computers 78, 80, and 82 monitor the signal strength of the base stations 72, 74, and 76. In some embodiments the mobile computers continuously monitor the signal strength, and in others, the mobile computers only monitor the signal strength when the SNR of the base station with which the mobile computer is currently communicating falls below an acceptable level. Similarly, to detect and connect to mobile computers as they are transferred between base stations, the base stations 72, 74, and 76 monitor the signal strength from the mobile computers 78, 80, and 82. A more detailed description of how the mobile computers are passed between base stations can be found in United States Patent No. 5,717,688 entitled WIRELESS LOCAL AREA NETWORK WITH ROAMING INDICATING MULTIPLE

COMMUNICATION RANGES by Belanger et al., the teachings of which are incorporated herein by reference in their entirety.

The present invention uses this monitoring of signal strength by both the base stations and the mobile computers, to locate and track a mobile computer and its user. An exemplary building layout is shown in Figure 3. The building includes hallway 90; offices 92, 93, 94, 95, 96, 97, and 98; and conference rooms 100 and 102. Base stations 72, 74, and 76 have been placed at various locations in the building. The mobile personal computers 78, 80, and 82 are also in the building, although they can move freely throughout the building.

The mobile personal computer 78 can monitor the strength of the signal from base stations 72, 74, and 76. As is known by those of skill in the art, the signals of a WLAN are attenuated as they propagate and as they pass through walls. Therefore, as monitored by mobile computer 78, the signal from base station 72 is stronger than the signals from base stations 74 and 76. This is because the signals from base stations 72 and 74 must travel a greater distance and must pass through more walls.

The signal strength from base stations 72, 74, and 76 will vary as the mobile computer 78 is moved around the building. For example, if the user of mobile computer 78 moved the computer into conference room 100, the signal strength of base station 74 as detected by mobile computer 78 would increase, as the distance between base station and mobile computer decreased, and as there would no longer be any walls between them. Similarly, the signal from base station 76, as detected by mobile computer 78, would increase in strength due to the decreased distance and decreased number of intervening walls. However, the signal from base stations 72 would decrease, since

mobile computer 78 would move further away. Therefore, it is possible to create a table listing known locations in the building, and the corresponding signal strengths from each of the base stations as received at those locations.

Turning to Figure 4, a method for creating the location versus signal strength table is shown. In Figure 4, diamonds with letters in them indicate locations where empirical measurements of the signal strength of the base stations 72, 74, and 76 have been taken. These measurements can then be compiled into a table, such as Table 1, shown below. Thus, location B has a higher SNR for base station 72 than location A because, while both are approximately equidistant from base station 72, location A is separated from the base station by the wall of office 92. The observation that distance and intervening walls decrease the signal strength, and thus decrease the SNR, is true for the rest of the entries in the table as well.

Location	SNR from Base 72	SNR from Base 74	SNR from Base 76
A	40 dB	20 dB	20 dB
B	45 dB	30 dB	30 dB
C	35 dB	25 dB	25 dB
D	30 dB	30 dB	30 dB
E	40 dB	35 dB	35 dB
F	25 dB	40 dB	30 dB
G	25 dB	45 dB	35 dB
H	20 dB	40 dB	40 dB
I	25 dB	35 dB	40 dB
J	30 dB	30 dB	35 dB

K	35 dB	25 dB	30 dB
L	40 dB	20 dB	40 dB
M	25 dB	30 dB	45 dB

Table 1

The strength of the radio frequency signals measured by the base station 76 or the mobile computer 20 can vary as a function of the orientation of the mobile computer 20 when performing the measurements. More particularly, the orientation of the computer is related to the position of the user, and it is the user's body that can create a significant difference in the detected signal strength. It is therefore necessary that the table used in determining the location of the mobile computer take this effect into account and be able to determine the location regardless of the orientation of the user with respect to the mobile computer. One method for taking this effect into account is to consider multiple orientations of the user's body to minimize the effects of signal attenuation due to the user's body.

The present invention also contemplates multiple measurements at each location to remove the effect of the random variables, such as air currents and radio interference, that can affect signal quality. Because these events are often short lived, multiple samples taken at one location over a period of time will yield different results. To remove the effect of the random variables, the calculated signal strength values over a period of time are averaged. This average value is then used in a table, such as Table 1 above. In such a manner the accuracy of the table, and thus the location determination, is enhanced.

Once a table relating signal strength to the position of the mobile computer 20, such as Table 1, is created, the mobile computer 20 can determine its location by finding the row of the table which most closely corresponds to the signal strengths detected by the mobile computer. For example, mobile computer 78 might detect a SNR of 38 dB from base station 72, 23 dB from base station 74, and 24 dB from base station 76. By comparing these values to Table 1, the mobile computer 78 determines that it is located at physical position C. This determination can be done in signal space. The signal space is an multi-dimensional space where the number of dimensions is equivalent to the number of base stations' signals which the mobile computer uses to determine its location. In Table 1 above, three base stations' signal strengths are determined at each physical location, so the signal space is a three-dimensional space. As will be known by those skilled in the art, unlike physical space, the signal space is not limited to three dimensions.

Each set of three measured signal strengths from the three base stations can define a point in the signal space. In one realization of this invention, the Euclidean distance between the point defined by the measured signal strengths and the points defined by the empirically derived signal strengths in Table 1 can be calculated. As is known by those of skill in the art, the Euclidean distance is the square root of the sum, over all the dimensions, of the difference between two points in each dimension, squared. In mathematical terms, the Euclidean distance, d, is defined as: $d = \sqrt{\sum_{i=1}^{n}(a_i - b_i)^2}$, where a_i is the value for the *i*th coordinate of point a and b_i is the value of the *i*th coordinate of point b, and n is a variable equivalent to the number of dimensions in the signal space.

The physical location of the mobile computer 20 is determined to be the same as the location whose corresponding empirically derived signal strengths in the table are the closest (as defined above) to the measured signal strengths. Thus, for the measured signal strengths of 68 dB, 53 dB, and 54 dB given as an example above, the location of mobile computer 78 would be determined to be location C. This is because the Euclidean distance in signal space between (38,23,24), which are the measured values, and (35,25,25), the stored values at point C, which were determined empirically during system set-up, is less than the Euclidean distance between (38,23,24) and any other point in the table. The mobile computer 20 therefore concludes that it is located at location C. The location of a mobile computer 20 can thus be determined through sensing the signal strength from each of a number of base stations. As is known by those skilled in the art, the Euclidean distance is just one possible distance metric. Other distance metrics such as sum of absolute value differences, or weighted Euclidean are also possible.

Rather than merely comparing the detected values to a single row of the table, the present invention also contemplates finding several rows of the table, each of which contains values similar to those observed. Such a multiple nearest neighbor approach, spatially averages multiple locations at which the empirically determined signal strengths from the base stations are similar to those measured by a mobile computer seeking to determine its location. As will be known by those of skill in the art, spatial averaging involves averaging the individual coordinate values of the locations. Therefore, it is necessary to define a consistent coordinate system, such as using a corner of the building as the origin (0,0). Returning to the example above, the values detected by mobile computer 78, namely 38 dB, 23 dB, and 24 dB, respectively are similar to the entries for a

number of rows in addition to row C selected above. Using the multiple nearest neighbor approach, we find rows A and B are also similar to the detected values. These three "nearest neighbors": A, B, and C, are spatially averaged to determine the location of mobile computer 78. As will be apparent to one of skill in the art, the multiple nearest neighbor approach can be implemented with any number of "neighbors".

A variation of the multiple nearest neighbor approach using weighting is also contemplated by the present invention. If one set of signal strength values are very similar to the values detected by the mobile computer 20, it may be that the position corresponding to those values is more accurate than any other position at which an empirical measurement was taken. That does not mean, however, that the multiple nearest neighbor approach cannot improve the accuracy of that position determination. However, because there exists a position which appears to be near the actual position of the mobile computer, only minor changes to that position should be caused as a result of the multiple nearest neighbor approach. In such a case, a weighted multiple nearest neighbor approach may be appropriate. A weighted multiple nearest neighbor approach multiplies the coordinates of each "neighbor" location by a weighting factor prior to averaging them. If a position appears to be a particularly good match, then the coordinates of that position would by multiplied by a larger weighting factor than the other positions. In such a manner, the weighted multiple nearest neighbor approach would cause less deviation from the perceived best position, yet would provide a minor position adjustment which could result in even greater accuracy.

The present invention also contemplates locating a mobile device by measuring the signal strength from the mobile device as received by several base stations. As will

be evident to those skilled in the art, such a method is the inverse of the method described above. Returning to Figure 2, a computer 84 can also be connected to the base stations 72, 74, and 76, through the network 70. Computer 84 can monitor the signal strength from a particular mobile computer 20 as received by the base stations near that mobile computer. Because it is connected to all of the base stations, the computer 84 can also generate the table which relates the position of the mobile computer 20 to the strength of the signal from the mobile computer as received by each of the base stations. Returning to Figure 4, as explained above, empirical data can be gathered by sampling the signal strength from the mobile computer, as it is moved throughout the building. In this case, however, the table generated by computer 84 as a result of the sampling will contain the signal strength of the signal from the mobile computer as detected at each base station, instead of the signal strength of the signal from each base station as detected at the mobile computer. The computer 84 can collect the signal strength information as received by each base station and create a table such as Table 2 below.

Location of User	SNR at Base 72	SNR at Base 74	SNR at Base 76
A	30 dB	10 dB	10 dB
B	35 dB	20 dB	20 dB
C	25 dB	15 dB	15 dB
D	20 dB	20 dB	20 dB
E	30 dB	25 dB	25 dB
F	15 dB	30 dB	20 dB
G	15 dB	35 dB	25 dB
H	10 dB	30 dB	30 dB

I	15 dB	25 dB	30 dB
J	20 dB	20 dB	25 dB
K	25 dB	15 dB	20 dB
L	30 dB	10 dB	30 dB
M	15 dB	20 dB	35 dB

Table 2

As can be seen from a comparison of Table 1 above and Table 2 above, the tables are similar with respect to the relationship between the signal strengths in any one row. Even though the signal strength measured at the mobile computer 20 and the base station 76 are similar in value, there is no requirement that they be so. The two signals travel the same path and encounter the same obstacles which degrade the signal. The only difference can be the power of the transmitting devices themselves: the base station, since it does not need to conserve power, may be transmitting at a higher power than the wireless network interface 53 on the mobile computer 20. For example, the Federal Communications Commission (FCC) allows wireless networks to use up to 1 Watt of transmitting power, which can be easily met by the base station. The wireless network interface 53, however, typically transmits in the 50-100 mW range so as to conserve the battery power of the mobile computer 20.

Therefore, as can be seen by comparing Table 1 and Table 2, the signals received by the base stations in Table 2 are weaker than those received by the mobile computer from the base stations in Table 1. However, because the signals in both directions are equally affected by distance and obstacles, the relationship between the signals in a row remains the same. For example, at location A in Table 1 the signal from base station 72

is stronger than the signals from base stations 74 and 76 because of the distance and the obstacles between location A and base stations 74 and 76. This is the same reason that in Table 2, at location A, the signal from the mobile computer at location A is stronger when detected by base station 72 than when detected by base stations 74 and 76. Because the mobile computer does not transmit its signals with as much power, the SNR is lower in Table 2 than in Table 1.

As described above, multiple measurements taken at several different orientations of the mobile computer 20 can be used to eliminate the effect of the user's body on the signal strength when creating a table such as Table 2. Additionally, as described above, taking multiple measurements at each location can improve the accuracy of the values in the table, as it minimizes the effects of random interference and noise.

The multiple nearest neighbor method described in detail above can also be used with the data in Table 2. For example, the computer 84 can determine that the strength of the signal from mobile computer 78, as shown in Figure 4, is 28 dB as detected by base station 72, 13 dB as detected by base station 74, and 14 dB as detected by base station 76. Comparing these values to Table 3, we find locations A, B, and C as the nearest "neighbors" to the values obtained. The nearest neighbors are then spatially averaged to calculate the location of mobile computer 78. As above, the use of the multiple nearest neighbor method requires the use of a consistent coordinate system. Also, a weighted multiple nearest neighbor approach, as described above, can be used with a table such as Table 3.

An alternative method to empirically deriving Tables 1 or 2 above, contemplated by the present invention, requires mathematically estimating the attenuation in the signal

as due to the distance between the transmitter and the receiver, and the intervening walls. As is known by those skilled in the art, the transmissions in a wireless network conform to general radio propagation theories. Most notably the signal strength of the transmissions becomes weaker as the distance from the transmitting source increases, and the signal strength of the transmissions decreases when the signals must pass through walls. Research into the field of electromagnetic waves has yielded a number of useful mathematical formulas. For example, it is known that signal strength decreases with distance. It is also known that walls attenuate signals by a determinable factor, known as the Wall Attenuation Factor (WAF). The WAF is dependent on the thickness of the wall, and the materials used in the construction of the wall. The WAF can be determined empirically by placing a receiver on one side of a wall and a transmitter on the other, and detecting the attenuation of the signal through the wall. One method for determining a WAF can be found in the article entitled "914 MHz Path Loss Prediction Models for Indoor Wireless Communications in Multifloored Buildings" by Scott Y. Seidel and Theorodre S. Rappaport, which appeared in IEEE Transactions On Antennas and Propagation, Volume 40, Number 2, February 1992, the teachings of which are hereby incorporated by reference.

The signal strength at a particular location can, therefore, be defined as the signal strength as attenuated by distance and walls that the signal had to pass through. In mathematical terms, the formula can be expressed as follows: the signal strength, or power P, at a given distance d is calculated as $P(d) = P(d_0) - 10n\log\left(\frac{d}{d_0}\right) + \begin{cases} nW(WAF) & nW < C \\ C(WAF) & nW \geq C \end{cases}$.

The first term is the signal strength at a reference distance d_0. The reference distance can be chosen to be a convenient distance and the signal strength at that distance can be

determined empirically. If the reference distance is chosen to be one meter from the emitter itself, then the signal strength may be available from the specifications of the device, eliminating the need for empirical determination. The second term in the equation provides the attenuation in the signal strength due to the distance between the point at which the signal strength is sought to be calculated, and the reference point at which the signal strength is known. The variable n is the path loss component which indicates the rate at which the signal strength decreases with distance. The second term is subtracted from the first term, and thus, reduces the reference signal strength if the desired point is further from the transmitter than the reference point. The third term in the equation quantifies the attenuation due to the number of walls the signal must pass through. The term nW represents the number of walls and the WAF can be determined empirically, as described above. Thus, the product of the two yields the attenuation due to all of the walls. As explained above, the WAF is a negative number, resulting in a reduction to the calculated signal strength. After a certain number of walls, however, the signal becomes so weak that further degradation is not mathematically significant. This practical limit is C walls, where C can be selected by the user to satisfy that user's accuracy requirements. After C number of walls, therefore, the attenuation factor can simply be expressed as C multiplied by the WAF.

The number of walls between a signal source and the location for which the signal strength is to be calculated can be determined by automated means. For example, in one realization of this invention, the building is divided into non-overlapping but connected rectangular regions, as defined by the walls inside the building. A straight line between the base station 76 and the location of the mobile personal computer 80, indicating the

path the signal would take when no walls are present are considered. Cohen-Sutherland Line Clipping Algorithm can then be used to determine the number of walls between the source and receiver. Line clipping is the deletion of a part of a line segment which lies outside a clip area. Once the line clipping is performed, the remaining line segment lies completely within a clip area. The algorithm divides the region outside of the clipping area into areas with "outcodes". Each digit of the binary outcode represents whether the particular region lies above, below, or to the left or right of a clipping area. As is shown in Figure 5, a four binary digit outcode can be used. The first digit indicates whether the region is above the clipping region 104. For example, regions 118, 120, and 106 are all above region 104, as indicated by the dashed lines, and those regions all have a binary 1 as the value of the first digit. The second digit indicates whether the region is below the clipping region 104. Thus, regions 114, 112, and 110 all have a binary 1 as the value of the second digit since they are below the clipping region 104. Regions 108 and 116 are adjacent to the clipping region and therefore both the first and second binary digits are 0, since adjacent regions are neither above nor below the clipping region. Similarly, the third binary digit indicates whether the region is to the right of the clipping region 104, and the fourth binary digit indicates whether the region is to the left of the clipping region. The clipping region 104 itself has an outcode of 0000 because, by definition, it is nether above, nor below, and neither to the left nor to the right of itself.

Once this subdivision occurs, all lines through the clipping region, such as lines 122 and 124 shown in Figure 5, are divided by the boundaries of the regions described above, as shown at points 126 and 128 for line 122, and points 130 and 132 for line 124. A key feature of the outcodes is that the binary digits which have a value of 1 correspond

to boundaries between the regions, which are crossed. For example, line 122 has two endpoints: one in region 0000 and another in region 1001. The significance of outcode 1001 is that the line must intersect the top and left boundaries because the first digit indicates it is above the clipping region and the last digit indicates it is to the left of the clipping region, as described above. Whenever a point on the line changes its outcode value, by definition the line has crossed a boundary. It is possible that this line intersects a number of rectangular regions. For example, the office layout from Figures 3 and 4 can be divided into regions with outcodes as shown in Figure 5. The Cohen-Sutherland Line Clipping Algorithm is described further in Chapter 3.11 of Computer Graphics Principles and Practice, Second Edition by Foley et al., published in 1990, the teachings of which are incorporated herein by reference.

Turning to Figure 6, at step 140, the floor schematic is entered into a computer as an input to the Cohen-Sutherland Line Clipping Algorithm. Similarly, at step 142 the locations of the base stations are entered, and at step 144 the locations at which the signal strength is to be calculated are entered. The Cohen-Sutherland Line Clipping Algorithm at step 146 will then determine, as described above, the number of walls between each of the base stations and the locations at which the signal strength is to be calculated. This number is then used in the signal strength equation, given above, at step 148.

In addition to the number of walls, the WAF, empirically derived as described above, is entered at step 150. At step 152, the limiting factor C is selected by the user. The variable n, the rate at which signal strength decreases with distance, is provided at step 154. The reference distance and the signal strength at that reference distance, as described above, are provided in steps 158 and 156 respectively. The signal strength

equation given above can then, at step 148, calculate the signal strength at each of the locations entered in step 144. The output of the signal strength equation is entered into a table, such as Table 1 or Table 2, above, at step 160.

The mathematical estimation can be used to derive both a table containing the values of the signal strength from various base stations as detected by a mobile computer 20 and the values of the signal strength from a mobile computer 20 as detected by various base stations. As would be known by those of skill in the art, the variables in the signal strength equation would be different depending on which method was used. For example, to calculate the signal strength from a base station, as detected by a mobile computer at a particular location, the reference distance should be set close to the base station, or even at one meter from the base station, as described above, and the term n would be the rate at which the signal strength of the base station decreased with distance. Conversely, to calculate the signal strength from a mobile computer 20 at a particular location, as detected by a base station, the reference distance should be set close to the mobile computer, such as one meter away, and the term n would be the rate at which the signal strength of the mobile computer 20 decreased with distance.

The present invention also contemplates providing for environmental factors by environmentally profiling the system. The base stations are all located at known locations, as shown in Figures 3 and 4. One base station could send out a signal to be received by the other base stations, in the same way that the base stations would receive a signal from a mobile computer. For example, with reference to Figure 3, base station 72 could emit a signal to be detected by base stations 74 and 76. Using a table generated by the signal strength equation given above, the computer 84 could receive the signal of base

station 72, as detected by base stations 74 and 76, and determine the location of base station 72. This would be done in the same manner that computer 84 would determine the location of a mobile computer 20 from its signal strength as detected at the base stations, as described above.

The computer 84 can then compare the calculated location to the known location of base station 72. If there is a difference between the two, the inputs to the variables in the signal strength equation, given above for estimating the signal strength at a particular location, can be varied. For example, the n value, or the WAF, could be changed, and a new table recalculated. This new table would then be used by computer 84 to calculate again the position of base station 72. The computer 84 could then again compare the new calculated location of base station 72 to the known location and determine the difference. The above iteration can be performed multiple times. The computer 84 could determine which values of the variables in the signal strength equation yielded the most accurate results, and then use those values to generate the table, which would, in turn, be used to calculate the position of the mobile computers. The values of the variables could also be passed to the mobile computer 20 along with a map of the building, so that it can generate a table within itself, and determine its location based on the strength of the signal from various base stations, as described above. As would be known by those of skill in the art, the variables in the signal strength equation could be varied beforehand, generating numerous tables. The above method could then be used to select the most accurate table of the group generated. In either case, the environmentally profiled tables could result in more accurate calculations. Because factors which affect signal strength,

such as the number of people present, can vary, the system can be programmed to profile and tune itself, as described above, multiple times.

An alternative environmental profiling mechanism can be implemented by empirically deriving more than once the table relating the position of the mobile computer to the signal strength. As described above, a table relating the position of the mobile computer to the signal strength, such as Tables 1 or 3, can be derived empirically. Such empirical derivations can be performed numerous times, under different environmental conditions, and at different times of the day. Environmental conditions can be impacted by the temperature, the number of people in the building, the amount of human traffic in the building, and whether it is day or night. Then, as above, the base stations could test the system by attempting to use the tables to determine the location of a given base station and then comparing the calculated location to the true location. The table that results in the greatest accuracy would then be used. In this way, the system could avoid the complexity of calculating the signal strength. As above, the system could be programmed to environmentally profile itself periodically.

As can be seen from the foregoing detailed description, the present invention is directed to a system and a method for determining the location of a mobile computer and its user based on the strength of wireless signals from the WLAN to which the computer is connected. The present invention can also be implemented by a dedicated system providing base stations and receiver/transmitters on the mobile computer. Similarly, the present invention can operate on any wireless mechanism, which does not require a line-of-site between the receiver and transmitter, such as radio frequency (RF) transmissions of varying wavelengths and ultra-sound transmissions. The present invention is equally

applicable to a wireless system that interconnects other mobile units, in addition to mobile personal computer 20, such as cordless phones, CB radios, two-way radios, or the like.

All of the references cited herein, including patents, patent applications, and publications, are hereby incorporated by reference in their entireties.

In view of the many possible embodiments to which the principles of this invention may be applied, it should be recognized that the embodiment described herein with respect to the drawing figures is meant to be illustrative only and should not be taken as limiting the scope of invention. For example, those of skill in the art will recognize that the elements of the illustrated embodiment shown in software may be implemented in hardware and vice versa or that the illustrated embodiment can be modified in arrangement and detail without departing from the spirit of the invention. Therefore, the invention as described herein contemplates all such embodiments as may come within the scope of the following claims and equivalents thereof.

CLAIMS

We claim:

1. A method for determining a location of a mobile unit, comprising: measuring a wireless signal strength; comparing the measured wireless signal strength to a table of wireless signal strengths and known locations of the mobile unit; finding a table entry whose wireless signal strength is closest, by distance in signal space, to the measured wireless signal strength; and, determining the location of the mobile unit with reference to the found table entry.

2. The method of claim 1 wherein the determining the location of the mobile unit with reference to the found table entry includes determining the location of the mobile unit to be proximate to a known location corresponding to the found table entry.

3. The method of claim 1 wherein the finding the table entry whose wireless signal strength is most similar to the measured wireless signal strength includes finding a plurality of table entries and wherein the determining the location of the mobile unit with reference to the found table entry includes determining the location of the mobile unit to be proximate to a spatial average of known locations corresponding to the found plurality of table entries.

4. The method of claim 3 wherein the determining the location of the mobile unit to be proximate to a spatial average of known locations corresponding to the found

plurality of table entries includes multiplying each known location by a weighting factor prior to the spatial averaging of the known locations.

5. The method of claim 1 wherein measuring the wireless signal strength includes measuring, at the mobile unit, a wireless signal strength of a base station, and wherein the table of wireless signal strengths and known locations of the mobile unit includes the wireless signal strength of the base station.

6. The method of claim 5 wherein the table of wireless signal strengths and known locations of the mobile unit is generated by a method comprising the steps of: measuring, at the mobile unit in a known location, the wireless signal strength of the base station; and entering, as an entry in the table, the known location and the measured wireless signal strength of the base station.

7. The method of claim 6 wherein the measuring of the wireless signal strength of the base station includes measuring, at the mobile unit in the known location, the wireless signal strength of the base station in a plurality of orientations of the mobile unit.

8. The method of claim 5 wherein the table of wireless signal strengths and known locations of the mobile unit is generated by a method comprising the steps of: mathematically estimating, at the mobile unit in a known location, the wireless signal

strength of the base station; and entering, as an entry in the table, the known location and the mathematically estimated wireless signal strength of the base station.

9. The method of claim 8 wherein the mathematically estimating, at the mobile unit in the known location, the wireless signal strength of the base station includes determining a reference wireless signal strength of the base station at a reference distance from the base station.

10. The method of claim 8 wherein the mathematically estimating, at the mobile unit in the known location, the wireless signal strength of the base station includes determining a distance between the base station and the known location.

11. The method of claim 8 wherein the mathematically estimating, at the mobile unit in the known location, the wireless signal strength of the base station includes determining an existing number of walls between the base station and the known location and determining a wall attenuation factor.

12. The method of claim 11 wherein the determining the existing number of walls between the base station and the known location includes using a line clipping algorithm.

13. The method of claim 11 wherein the determining the existing number of walls between the base station and the known location includes determining a practical limit number of walls between the base station and the known location.

14. The method of claim 1 wherein measuring the wireless signal strength includes measuring, at a base station, a wireless signal strength of the mobile unit, and wherein the table of wireless signal strengths and known locations of the mobile unit includes the wireless signal strength of the mobile unit.

15. The method of claim 14 wherein the table of wireless signal strengths and known locations of the mobile unit is generated by a method comprising the steps of: measuring, at the base station, the wireless signal strength of the mobile unit in a known location; and entering, as an entry in the table, the known location and the measured wireless signal strength of the mobile unit in the known location.

16. The method of claim 15 wherein the measuring of the wireless signal strength of the mobile unit in the known location includes measuring, at the base station, the wireless signal strength of the mobile unit in a plurality of orientations at the known location.

17. The method of claim 14 wherein the table of wireless signal strengths and known locations of the mobile unit is generated by a method comprising the steps of: mathematically estimating, at the base station, the wireless signal strength of the mobile

unit in a known location; and entering, as an entry in the table, the known location and the mathematically estimated wireless signal strength of the mobile unit in the known location.

18. The method of claim 17 wherein the mathematically estimating, at the base station, the wireless signal strength of the mobile unit in the known location includes determining a reference wireless signal strength of the mobile unit in the known location at a reference distance from the mobile unit in the known location.

19. The method of claim 17 wherein the mathematically estimating, at the base station, the wireless signal strength of the mobile unit in the known location includes determining a distance between the base station and the known location.

20. The method of claim 17 wherein the mathematically estimating, at the base station, the wireless signal strength of the mobile unit in the known location includes determining an existing number of walls between the base station and the known location and determining a wall attenuation factor.

21. The method of claim 20 wherein the determining the existing number of walls between the base station and the known location includes using a line clipping algorithm.

22. The method of claim 20 wherein the determining the existing number of walls between the base station and the known location includes determining a practical limit number of walls between the base station and the known location.

23. A computer-readable medium having computer-executable instructions for performing steps, comprising: measuring a wireless signal strength; comparing the measured wireless signal strength to a table of wireless signal strengths and known locations of the mobile unit; finding a table entry whose wireless signal strength is closest, by distance in signal space, to the measured wireless signal strength; and, determining the location of the mobile unit with reference to the found table entry.

24. The computer-readable medium of claim 23 wherein the determining the location of the mobile unit with reference to the found table entry includes determining the location of the mobile unit to be proximate to a known location corresponding to the found table entry.

25. The computer-readable medium of claim 23 wherein the finding the table entry whose wireless signal strength is most similar to the measured wireless signal strength includes finding a plurality of table entries and wherein the determining the location of the mobile unit with reference to the found table entry includes determining the location of the mobile unit to be proximate to a spatial average of known locations corresponding to the found plurality of table entries.

26. The computer-readable medium of claim 25 wherein the determining the location of the mobile unit to be proximate to a spatial average of known locations corresponding to the found plurality of table entries includes multiplying each known location by a weighting factor prior to the spatial averaging of the known locations.

27. The computer-readable medium of claim 23 wherein measuring the wireless signal strength includes measuring, at the mobile unit, a wireless signal strength of a base station, and wherein the table of wireless signal strengths and known locations of the mobile unit includes the wireless signal strength of the base station.

28. The computer-readable medium of claim 27 wherein the table of wireless signal strengths and known locations of the mobile unit is generated by computer-executable instructions for performing steps, comprising: measuring, at the mobile unit in a known location, the wireless signal strength of the base station; and entering, as an entry in the table, the known location and the measured wireless signal strength of the base station.

29. The computer-readable medium of claim 28 wherein the measuring of the wireless signal strength of the base station includes measuring, at the mobile unit in the known location, the wireless signal strength of the base station in a plurality of orientations of the mobile unit.

30. The computer-readable medium of claim 27 wherein the table of wireless signal strengths and known locations of the mobile unit is generated by computer-executable instructions for performing steps, comprising: mathematically estimating, at the mobile unit in a known location, the wireless signal strength of the base station; and entering, as an entry in the table, the known location and the mathematically estimated wireless signal strength of the base station.

31. The computer-readable medium of claim 30 wherein the mathematically estimating, at the mobile unit in the known location, the wireless signal strength of the base station includes determining a reference wireless signal strength of the base station at a reference distance from the base station.

32. The computer-readable medium of claim 30 wherein the mathematically estimating, at the mobile unit in the known location, the wireless signal strength of the base station includes determining a distance between the base station and the known location.

33. The computer-readable medium of claim 30 wherein the mathematically estimating, at the mobile unit in the known location, the wireless signal strength of the base station includes determining an existing number of walls between the base station and the known location and determining a wall attenuation factor.

34. The computer-readable medium of claim 33 wherein the determining the existing number of walls between the base station and the known location includes using a line clipping algorithm.

35. The computer-readable medium of claim 33 wherein the determining the existing number of walls between the base station and the known location includes determining a practical limit number of walls between the base station and the known location.

36. The computer-readable medium of claim 23 wherein measuring the wireless signal strength includes measuring, at a base station, a wireless signal strength of the mobile unit, and wherein the table of wireless signal strengths and known locations of the mobile unit includes the wireless signal strength of the mobile unit.

37. The computer-readable medium of claim 36 wherein the table of wireless signal strengths and known locations of the mobile unit is generated by computer-executable instructions for performing steps, comprising: measuring, at the base station, the wireless signal strength of the mobile unit in a known location; and entering, as an entry in the table, the known location and the measured wireless signal strength of the mobile unit in the known location.

38. The computer-readable medium of claim 37 wherein the measuring of the wireless signal strength of the mobile unit in the known location includes measuring, at

the base station, the wireless signal strength of the mobile unit in a plurality of orientations at the known location.

39. The computer-readable medium of claim 36 wherein the table of wireless signal strengths and known locations of the mobile unit is generated by computer-executable instructions for performing steps, comprising: mathematically estimating, at the base station, the wireless signal strength of the mobile unit in a known location; and entering, as an entry in the table, the known location and the mathematically estimated wireless signal strength of the mobile unit in the known location.

40. The computer-readable medium of claim 39 wherein the mathematically estimating, at the base station, the wireless signal strength of the mobile unit in the known location includes determining a reference wireless signal strength of the mobile unit in the known location at a reference distance from the mobile unit in the known location.

41. The computer-readable medium of claim 39 wherein the mathematically estimating, at the base station, the wireless signal strength of the mobile unit in the known location includes determining a distance between the base station and the known location.

42. The computer-readable medium of claim 39 wherein the mathematically estimating, at the base station, the wireless signal strength of the mobile unit in the

known location includes determining an existing number of walls between the base station and the known location and determining a wall attenuation factor.

43. The computer-readable medium of claim 42 wherein the determining the existing number of walls between the base station and the known location includes using a line clipping algorithm.

44. The computer-readable medium of claim 42 wherein the determining the existing number of walls between the base station and the known location includes determining a practical limit number of walls between the base station and the known location.

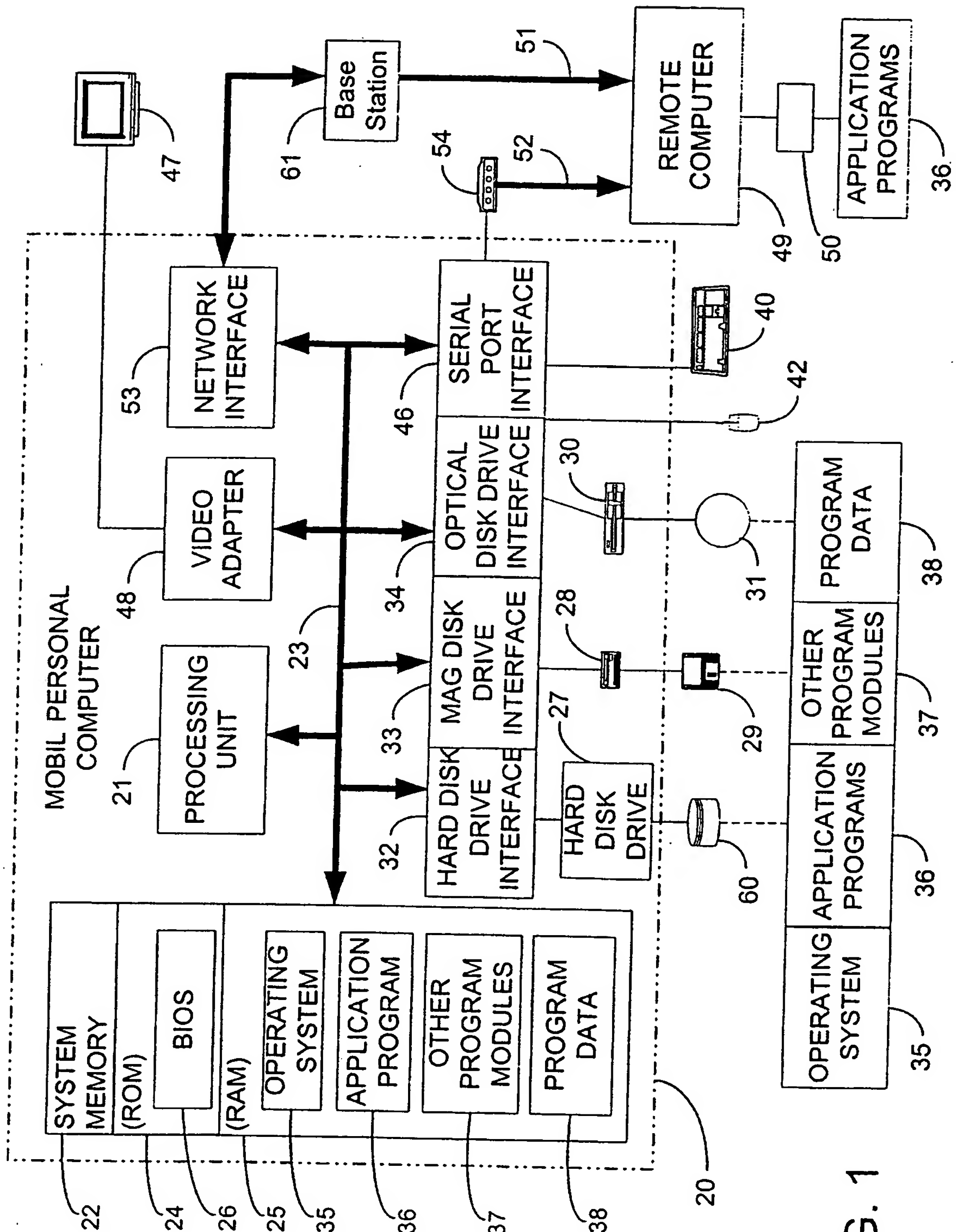

MOBIL PERSONAL COMPUTER
PROCESSING UNIT
VIDEO ADAPTER
NETWORK INTERFACE
SYSTEM MEMORY
(ROM)
BIOS
(RAM)
OPERATING SYSTEM
APPLICATION PROGRAM
OTHER PROGRAM MODULES
PROGRAM DATA
HARD DISK DRIVE INTERFACE
MAG DISK DRIVE INTERFACE
OPTICAL DISK DRIVE INTERFACE
SERIAL PORT INTERFACE
HARD DISK DRIVE
Base Station
REMOTE COMPUTER
APPLICATION PROGRAMS
OPERATING SYSTEM
APPLICATION PROGRAMS
OTHER PROGRAM MODULES
PROGRAM DATA
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
40
42
46
47
48
49
50
51
52
53
54
60
61

FIG. 1

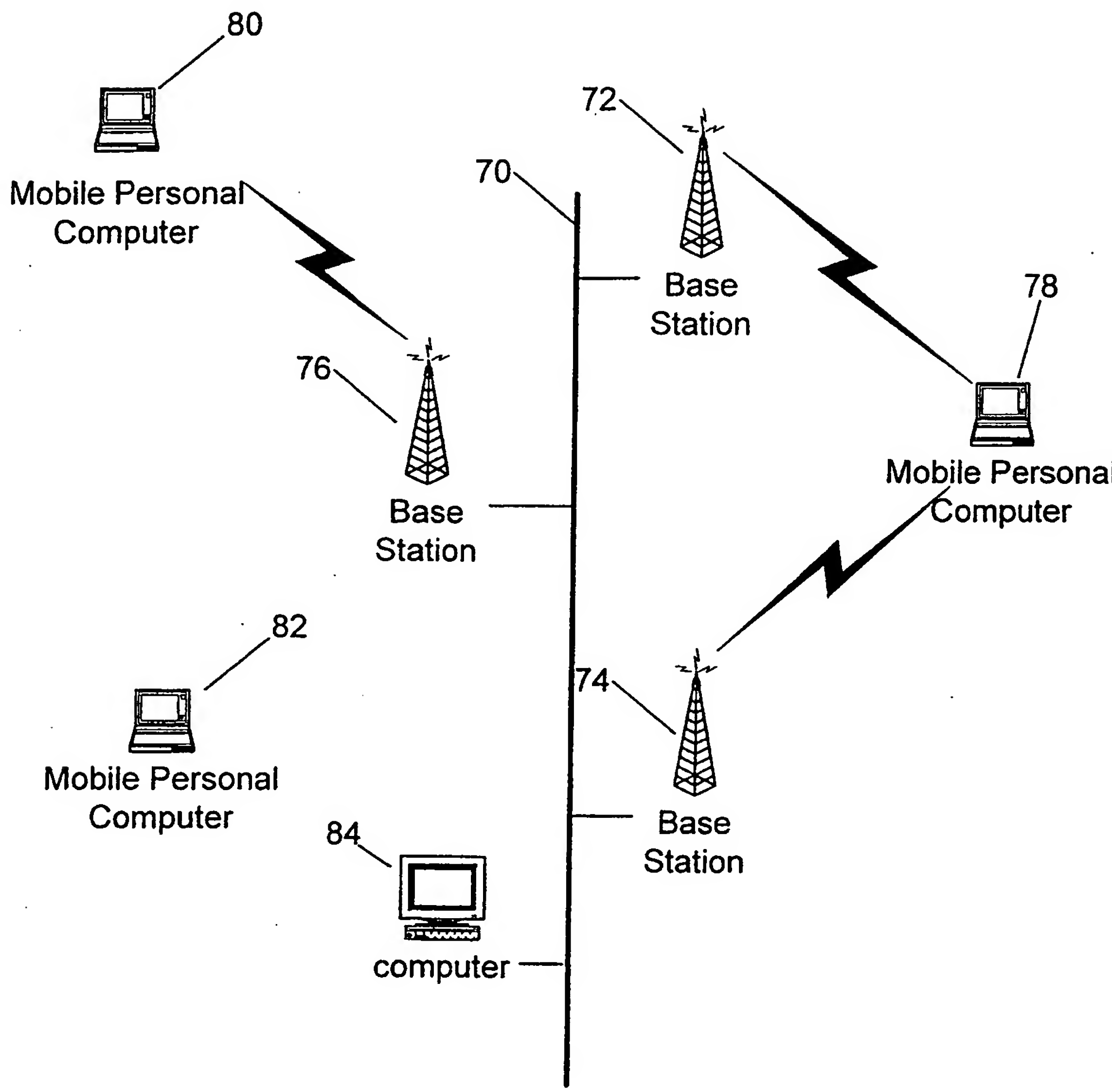

80
Mobile Personal
Computer
72
70
Base
Station
78
76
Mobile Personal
Computer
Base
Station
82
74
Mobile Personal
Computer
Base
Station
84
computer

FIG. 2

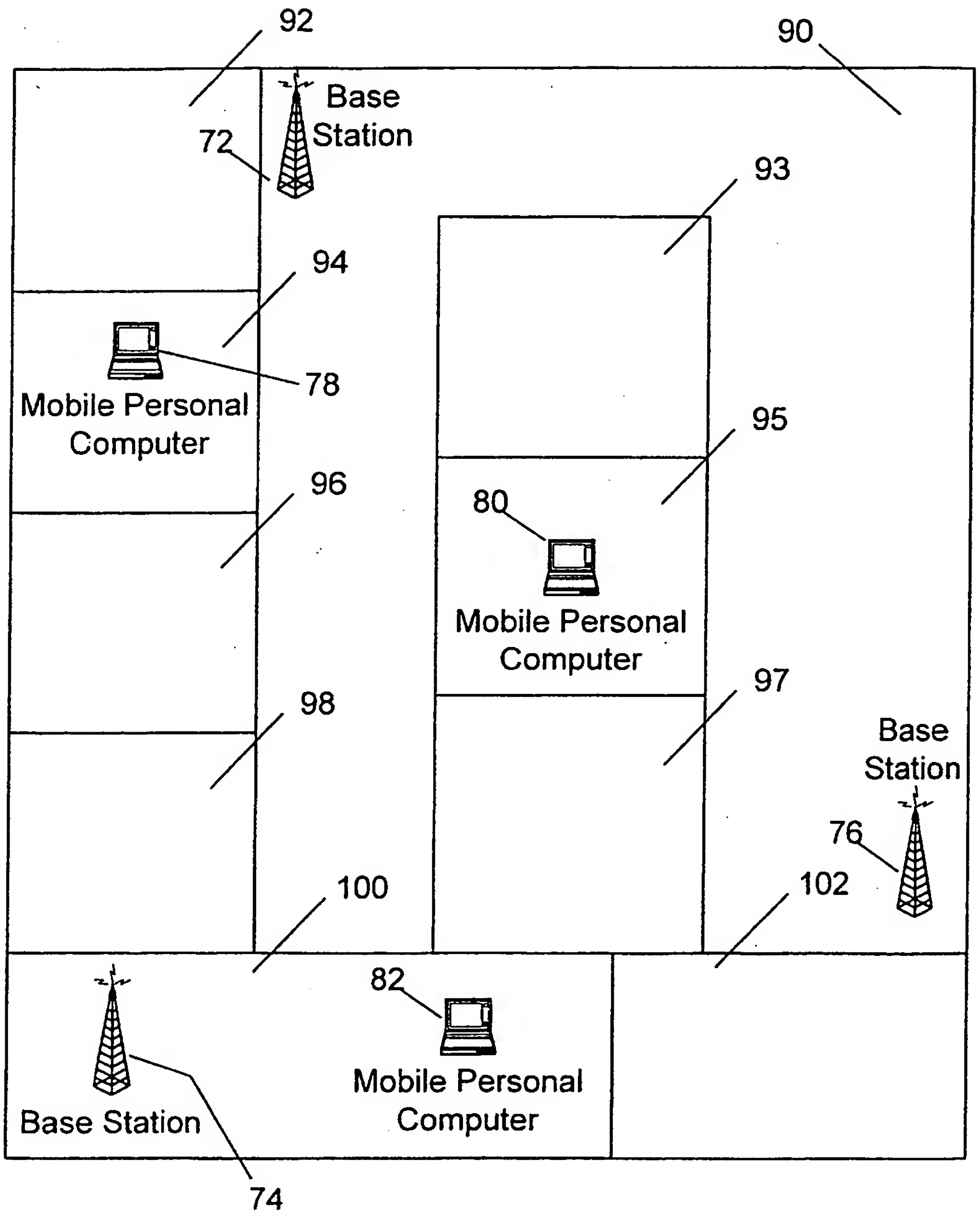

92
90
Base
Station
72
93
94
78
Mobile Personal
Computer
95
96
80
Mobile Personal
Computer
98
97
Base
Station
76
100
102
82
Mobile Personal
Computer
Base Station
74

FIG. 3

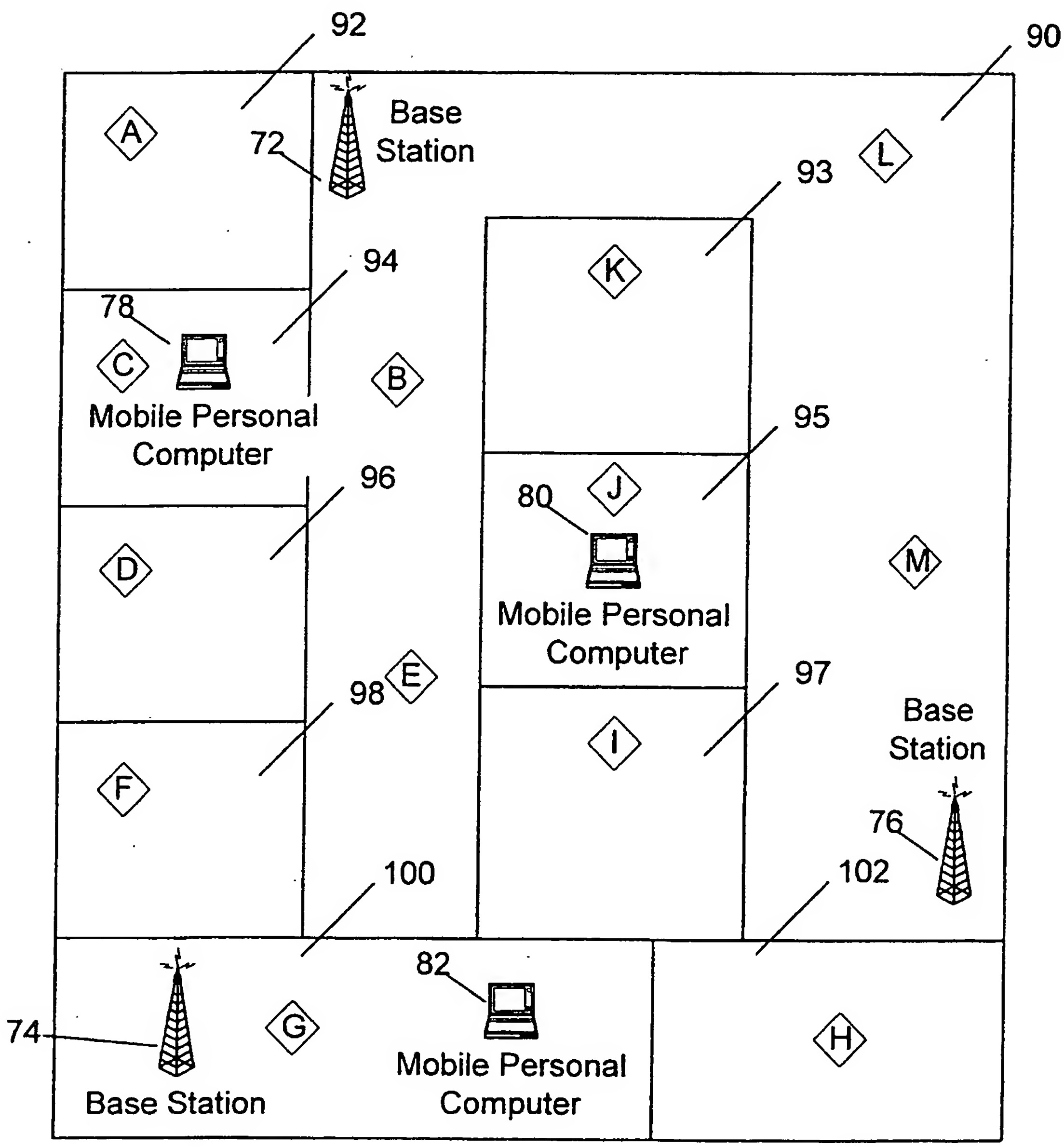

92
90
A
72
Base
Station
93
L
94
K
78
C
B
Mobile Personal
Computer
95
96
J
80
M
D
Mobile Personal
Computer
98
E
97
Base
Station
I
F
76
100
102
82
74
G
H
Base Station
Mobile Personal
Computer

FIG. 4

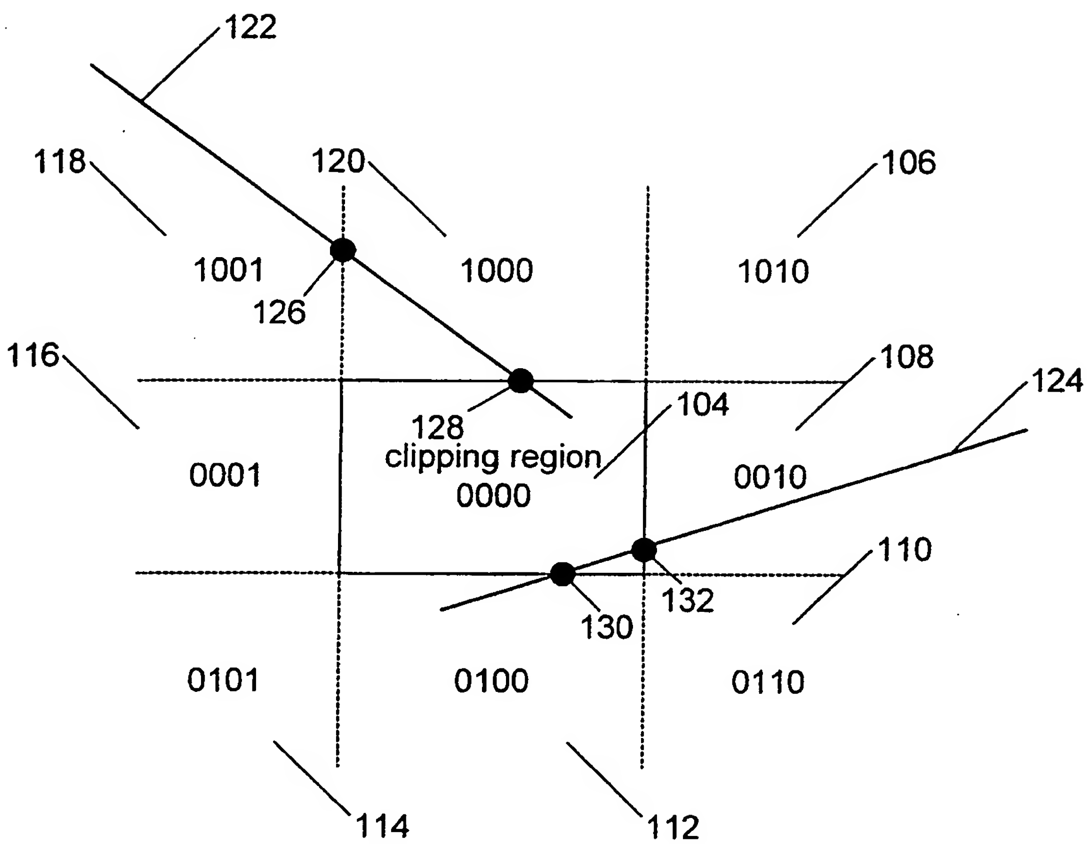

122
118
120
106
1001
1000
1010
126
116
108
124
104
128
clipping region
0000
0001
0010
110
132
130
0101
0100
0110
114
112

FIG. 5

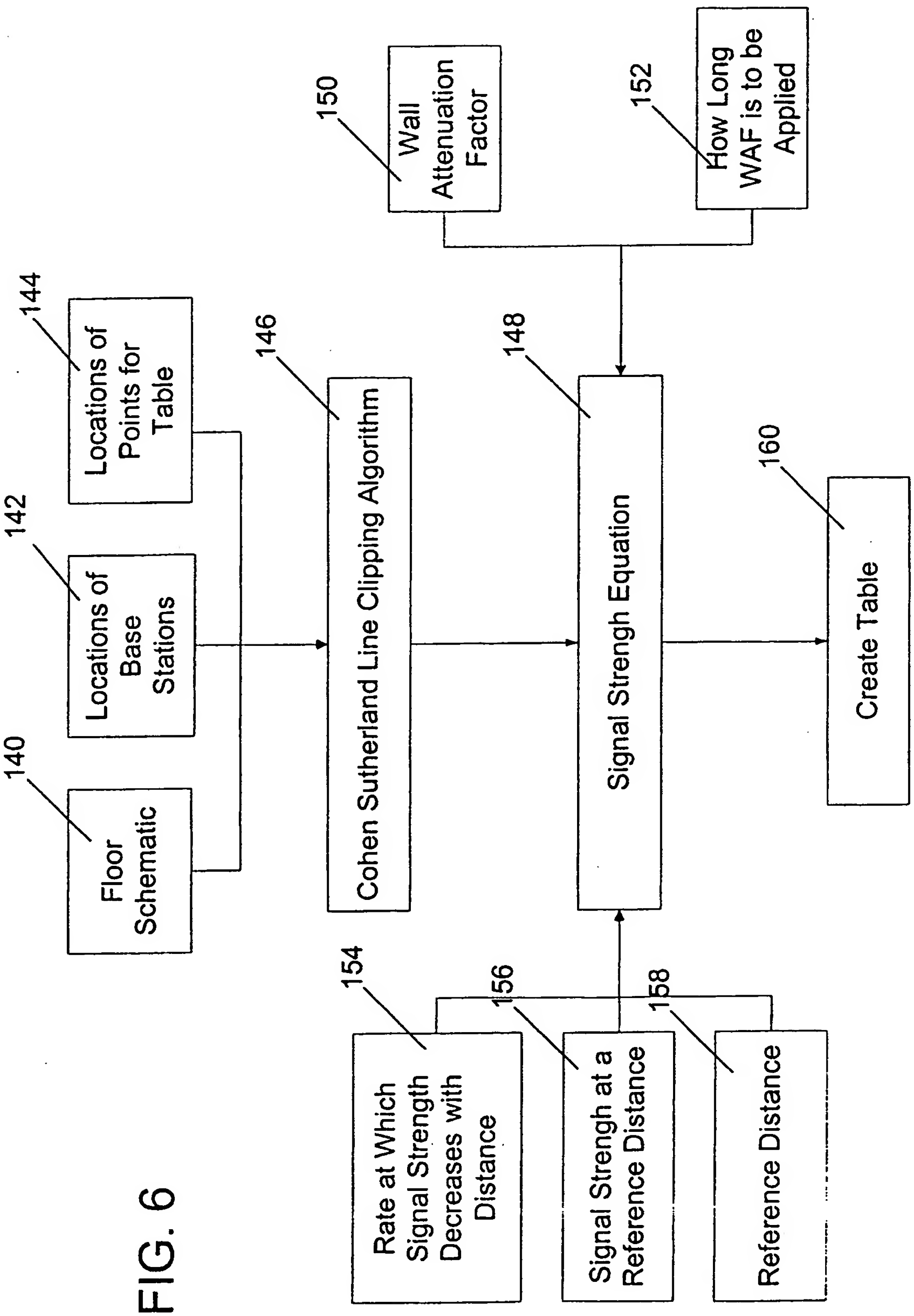

Floor Schematic
140
Locations of Base Stations
142
Locations of Points for Table
144
Cohen Sutherland Line Clipping Algorithm
146
Signal Strengh Equation
148
Wall Attenuation Factor
150
How Long WAF is to be Applied
152
Rate at Which Signal Strength Decreases with Distance
154
Signal Strengh at a Reference Distance
156
Reference Distance
158
Create Table
160

FIG. 6